A MUSCLE PROFILE OF VALUE ADDED BEEF FROM THE CHUCK AND ROUND

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NOMENCLATURE

°C	degree (s) Celsius
cm	centimeter (s)
d	day (s)
g	gram (s)
h	hour (s)
IMPS	Institutional Meat Purchase Specifications
kg	kilogram (s)
kN	kilonewton
min	minute (s)
mm	millimeter (s)
n	sample size
NAMP	North American Meat Processors Association
s	second (s)
USDA	United States Department of Agriculture
wt	weight
%	percent
>	greater than
<	less than

FORMAT OF THESIS

This Thesis is presented in the Journal of Animal Science style format, as outlined by the Oklahoma State University graduate college style manual. The use of this format allows for individual chapters to be prepared for submission to scientific journals.

CHAPTER I

INTRODUCTION

The beef industry is constantly in a battle with other protein sources for a share of the consumer's food dollar. Fortunately, beef demand has begun to increase after years of decline. According to the National Cattlemen's Beef Association, beef demand has increased more than three percent since 2000 (NCBA, 2003). Part of this increase in demand is a direct result of an aggressive advertising campaign and the introduction of new, innovative beef items. Termed "Value-Added Beef", these items include convenience items, as well as, new and improved muscle cuts showing the beef industry is attempting to target consumer preferences. While some of these new items include chuck and round cuts, most of the monetary value of a beef carcass is still derived from the rib and loin, which comprise less than 30% of the beef carcass on a weight basis. Whereas, beef chuck and round comprise over 50% of the beef carcass on a weight basis, but unfortunately are typically fabricated into low-priced roasts, steaks, or ground beef. Moreover, these roasts and steaks typically consist of numerous muscles, which can account for variations in palatability and ultimately hinder the marketability and acceptability of these cuts.

It has been suggested that the beef chuck, which comprises approximately 26 to 27% of the beef carcass on a weight basis, is perhaps the most under utilized wholesale cut of the beef carcass (Cecchi et al., 1988). Many researchers have documented the palatability of certain chuck muscles such as the infraspinatus, which has proven to be very tender when evaluated using Warner-Bratzler shear force and/or trained sensory panel evaluations (Cecchi et al., 1988; Patterson and Parrish, 1986; McKeith et al., 1985; Ramsbottom and Strandine, 1948). While the palatability of certain chuck muscles is well documented, little has been done to capitalize on this information. Furthermore, the inconsistency and sometimes less than desirable palatability of certain chuck and round muscles has also been documented to some extent.

Today many techniques are being utilized to improve the palatability of beef from the chuck and round, in an effort to improve consistency and add value to the carcass. Several of these methods include blade tenderization, marination, and the use of exogenous proteolytic enzymes. The objective of this study was to evaluate the potential for developing palatable steaks, suitable for foodservice establishments, from underutilized beef muscles. To carry out this study, four chuck muscles (infraspinatus, triceps brachii, teres major, and supraspinatus) and four round muscles (rectus femoris, vastus lateralis, biceps femoris, and semimembranosus) that had previously been identified by work conducted at the University of Nebraska and the University of Florida were utilized (Von Seggern, 2000; Brickler, 2000). Three USDA quality grades (Choice, Select, and Standard) were sampled to determine the effect of mechanical tenderization and marination on the Warner-Bratzler shear force, trained sensory panel evaluations, and consumer ratings of steaks produced from individual muscles coming from the beef chuck and round.

CHAPTER II

REVIEW OF LITERATURE

THE BEEF CHUCK AND ROUND

Numerous research has been conducted to determine the physical and chemical properties of various beef chuck and round muscles. Such work can be traced back as early as the 1940's with the work of Ramsbottom, Strandine, and Koonz or more recently to the research conducted at the University of Florida and the University of Nebraska. The majority of this research has focused on the chemical or physical properties of these muscles as determined by Warner-Bratzler shear force and trained sensory panel analysis. While this is useful and important information, the ultimate goal should be to determine consumer's acceptance of these muscles/cuts at the foodservice and retail level, and the economic feasibility for packers to isolate these individual muscles. Palatability, fabrication time, labor, and yield will ultimately determine the acceptability and feasibility of these muscles. It will also be important to determine if certain postmortem practices can be employed to improve the palatability and consistency of these muscles to increase their acceptance at the consumer level. If it can be determine that consumers are willing to accept these muscles at the foodservice or retail level, the utilization of these muscles could be an important means of increasing the value of the chuck and round and ultimately the beef carcass as a whole.

When developing new or different food items the palatability of those items is of the utmost concern. Within the meat industry, palatability is most often described as the juiciness, tenderness, and flavor of the cooked product. Of these three attributes tenderness is overwhelmingly recognized as the most important factor. According to Forrest et al. (1975), no palatability factor has been studied more than tenderness. Koohmaraie (1988) stated "tenderness is the predominant quality determinant and probably the most important organoleptic characteristic of red meat." Accordingly, recent research conducted by Boleman et al. (1997) showed that consumers are actually willing to pay a premium for guaranteed tender products. However, the perception of tenderness has many various components and can differ between consumers. The perception of tenderness, as described by Forrest et al. (1975), is thought to be affected by the following conditions:

1. *Softness to tongue and cheek* is the tactile sensation resulting from contact of the meat with tongue and cheek.

2. *Resistance to tooth pressure* relates to the force needed to sink the teeth into meat.

3. *Ease of fragmentation* is an expression of the ability of the teeth to cut across the fibers.

4. *Mealiness* is an exaggerated type of fragmentation. Small particles cling to the tongue, gums, and cheeks and give the sensation of dryness.

5. *Adhesion* denotes the degree to which the fibers are held together.

6. *Residue after chewing* is detected as that connective tissue remaining after most of the sample has been masticated.

While tenderness is unquestionably very important, one cannot downplay the roles of the other palatability factors. Regardless of the tenderness of a product, unacceptable flavor will be considered less than desirable by consumers. Flavor and aroma have been attributed to causing many of the psychological and physiological responses experienced when meat is eaten (Forrest et al., 1975). Accordingly juiciness is also very important; it is believed that in some instances increased juiciness can result in the perception of increased tenderness. According to Forrest et al. (1975): "Meat juices play an important role in conveying the overall impression of palatability to the consumer. They contain many of the important flavor components, and assist in the process fragmenting and softening the meat during chewing. Regardless of the other virtues of meat, the absence of juiciness severely limits its acceptability, and destroys its unique palatability characteristics." Because palatability and its attributes are very important to consumer satisfaction it has long been the practice of the meat industry to try and improve or at least control these attributes through various postmortem treatments and USDA quality grading.

Postmortem Treatment and Beef Palatability

Mechanical Tenderization. Mechanical or blade tenderization, often referred to as "needling", has long been employed to improve the tenderness of beef. As indicated by both National Beef Tenderness Surveys (Brooks et al., 2000; Morgan et al., 1991), there are consistent tenderness problems associated with beef round and chuck subprimals. Numerous research has shown that mechanical tenderization improves the tenderness of beef by lowering shear force values and/or improving trained sensory panel ratings (Jeremiah et al., 1999; Pringle et al., 1998; Boyd et al., 1978; Glover et al., 1977; Savell et al., 1977). Mechanical tenderization consists of passing steaks or sub-primals through a bank of needles or rotary macerator (Romans et al., 1994). It is believed that this improvement in tenderness is a direct result of the physical disruption of muscle fibers and connective tissue as the blades or needles penetrate the meat.

Previous research indicates that mechanical tenderization can also improve other palatability attributes of certain bovine muscles. Jeremiah et al. (1999) reported that mechanical tenderization improved the flavor desirability and overall palatability of certain round muscles as perceived by trained sensory panelists, while Pringle et al. (1998) reported that mechanical tenderization also improved the overall palatability scores of top sirloin steaks. Jeremiah et al. (1999), Pringle et al. (1998), and Savell et al. (1977) have all shown that mechanical tenderization lowers the amount of detectible connective tissue in certain muscles as perceived by trained sensory panelists.

Unfortunately, previous research has also indicated that mechanical tenderization can actually lower palatability ratings or at least certain palatability attributes in some instances. Jeremiah et al. (1999), Pringle et al. (1998), Medeiros et al. (1988), and Savell et al. (1977) all reported that mechanical tenderization lowered the juiciness of steaks from certain muscles as perceived by trained sensory panelists, while Boyd et al. (1978) reported that mechanical tenderization significantly decreased trained sensory panel flavor scores. However, Glover et al. (1977) reported that none of the variation in the flavor or juiciness of round and loin steaks could be attributed to mechanical tenderization in their study. Savell et al. (1977) also reported that mechanically tenderized loin steaks were rated as more mealy than non-tenderized loin steaks.

While there was no microbial aspect to this project, mechanical tenderization does introduce the potential for contamination. Therefore it is an important issue to consider because food safety is on the minds of so many consumers. Research conducted by Boyd et al. (1978) showed that semimembranosus muscles passed through a mechanical tenderizer four times had significantly higher microbial counts (both aerobic and anaerobic microorganisms) than samples passed through zero, one, and two times. While microbial counts did increase with each number of passes, the difference in microbial counts between the treatment groups (zero, one, or two passes) was not significantly different. The work of Raccach and Henrickson (1979) showed there was no difference in the aerobic plate counts of tenderized and non-tenderized biceps femoris muscles taken from the interior of the muscle. However, Raccach and Henrickson (1979) attribute this to the sanitary condition of the tenderizer, and mentioned that under unsanitary conditions mechanical tenderization could aid in the proliferation of microbial organisms, resulting in a shorter shelf life and potentially posing a public health risk.

Marination. The Oxford English Dictionary (Simpson and Weiner, 1989) defines a marinade as a pickle, generally composed of wine and vinegar, with herbs and spices, in which fish or meat is steeped. The marination of meat items has long been utilized to improve palatability. Unfortunately, excluding calcium chloride marination, there has been very little literature published about the effects of marination on beef palatability. Until recently the application of marinades generally occurred in the home or at the foodservice establishment, however, with the upstart of companies such as National Steak and Poultry in Owasso, OK we are beginning to see the commercial application of marinades at the processing level. Marinades can potentially improve meat palatability through the addition of flavor, increase in juiciness, and improvement of tenderness.

Research conducted by Howat et al. (1983) and Wenham and Locker (1976) have shown that marination utilizing weak acids were effective in lowering shear force values and improving sensory panel scores in semimembranosus and sternomandibularis muscles, respectively. Wenham and Locker (1976) were also able to show that the marination of sternomandibularis samples for 8 h and 43 h resulted in a weight gain of 8% and 19%, respectively; and most of this extra moisture was retained after cooking. However, they also reported that marination had no effect on juiciness as perceived by sensory panelists. While both articles have show that marination is effective on cuts of questionable tenderness, Wenham and Locker (1976) went on to show that marination is only marginally effective when used on higher quality cuts of meat such as longissimus dorsi muscle. This led the authors to believe that the major effect of marination is on connective tissue. This corresponds in part, with the conclusions of Howet et al. (1983) who hypothesized that the effect of the marination may be due to increased hydration of the muscle fiber and solubilization of collagen. Whenaham and Locker (1976) went on to conclude that for high quality steaks, the introduction of exotic flavors might be the major benefit of marination.

Exogenous Proteolytic Enzymes. Exogenous proteolytic enzymes are often used to improve the tenderness of less tender meat items. Their use can be traced back at least 500 years to Mexican-Indians wrapping their meat in leaves from the papaya tree (Tucker and Woods, 1995). The three most commonly used proteolytic enzymes are derived from tropical plants: papain: papaya; bromelin: pineapple; and ficin: fig (Romans et al., 1994). However, some proteolytic enzymes derived from bacterial and fungal origins such as

Aspergillus oryzae are available and approved for use with food products. Proteolytic enzymes work by degrading muscle fibers and/or connective tissue (stromal proteins) to different degrees (Romans et al., 1994). Fawcett and McDowell (1987) describe this protein degradation as taking two basic forms:

1. Complex peptides are hydrolyzed into a few smaller and more flavorful proteins (endo-peptidase activity).

2. Small units are lopped off the end of the more complex chain, which tends to produce less acceptable textural and flavor changes.

According to Fawcett and McDowell (1987) most commercially available enzymatic tenderizers are nonspecific and therefore breakdown both muscle fibers and collagen. Previous research has also suggested that many of the commercially available enzymes, papain in particular, have the potential to over tenderize meat products resulting in a mushy texture that is unsatisfactory to trained sensory panelists (Bowling, 1980). It has been suggested that the development of a more specific proteolytic enzyme that does not over tenderize meat would be beneficial to the meat industry. The fungal enzyme *Aspergillus oryzae* is believed to be such an enzyme, however, information about its effectiveness is sparse and often conflicting. Research conducted by Gerelt et al. (2000) and information available on the Texas A&M University Meat Science website suggest that *Aspergillus oryzae* is effective at disrupting connective tissue. The conclusions made by Gerelt et al. (2000) are based on the disruption of intramuscular connective tissue as seen on scanning electronmicrographs of samples prepared from *Aspergillus oryzae* treated meat samples. However, Ashie et al. (2002) concluded that *Aspergillus oryzae* did not hydrolyze collagen in beef semimembranosus and deep pectoral muscles when measured according to the method of Cronlund and Woychik (1987). Both Gerelt et al.

(2000) and Ashie et al. (2002) do agree, however, that *Aspergillus oryzae* does degrade myosin and improves tenderness as measured via trained sensory panel evaluations and Warner-Bratzler shear force determination, respectively. They also both agree that *Aspergillus oryzae* is not as effective as papain at tenderizing meat, but they both suggest that *Aspergillus oryzae* is a more suitable proteolytic enzyme for meat tenderization, presumably because over tenderization is less of an issue. Ashie et al. (2002) further support this conclusion by demonstrating that *Aspergillus oryzae* does not significantly affect tenderness during refrigerated storage beyond day 1 of storage suggesting that the tenderizing effect of *Aspergillus oryzae* occurs primarily during cooking. This conclusion, if further substantiated, could be very useful at the processing level.

Postmortem Aging. The use of postmortem aging to improve palatability attributes such as tenderness and flavor has been utilized for quite some time. It is believed that the first scientific evidence that postmortem aging improves tenderness was reported by Lehmann in 1907 (Koohmaraie, 1988). There are two different types of postmortem aging that impart distinctly different types of flavors: wet aging and dry aging. Wet aging, which is most common in industry, involves aging sub-primals or cuts in vacuum bags and is thought to impart some acidic flavors. Dry aging, which is less common and done more for upscale establishments, involves the aging of sub-primals or carcasses exposed to air. Dry aging is thought to impart more woody or nutty flavors. The production of these flavor compounds is believed to be the result of microbes such as yeasts and in some cases molds (Forrest et al., 1975). Others suggest that these flavors might be the result of the oxidation of fatty acids. Both wet and dry aging are thought to have the same effect on tenderization, however, the rate and extent to which postmortem aging effects tenderness can vary widely (Koohmaraie, 1996). This variation can depend on many factors including animal age, sex, breed and muscle type (Geesink et al., 1995). According to Stuby-Souva et al. (1994) tenderness differences occur between carcasses, between muscles in the same carcass, and within individual muscles. Muscle fiber type even plays a role in rate of tenderization, with fast-twitch-glycolytic muscles aging more rapidly than slow-twitch-oxidative muscles (Geesink et al., 1995). The time allotted for postmortem aging can also vary widely, however, according to Koohmaraie (1996) the optimum length of time for postmortem aging to maximize the tenderizing effects is 10-14 days. It is important to note that postmortem aging and a muscles overall response does not guarantee tenderness. While a muscle may respond very well to postmortem aging it may in fact still remain very tough, because everything is relative to its initial tenderness point. The muscles in this study were aged for 21 days postmortem in order to optimize tenderizing effects and to most closely mimic the amount of aging typically seen in the foodservice industry.

The action by which postmortem aging affects tenderness is not completely understood. According to Koohmaraie (1996) the tenderizing effect of postmortem aging is most likely due to the proteolysis of myofibrillar and associated proteins such as titin, nebulin, troponin-T, desmin, and vinculin. The actual proteases involved in this tenderization are also not completely understood and have been widely debated until recently. Most researchers now agree that calpains are most likely the proteases involved. According to Koohmaraie (1996) a protease must meet three criteria in order to be a candidate for postmortem tenderization:

1. The protease must be endogenous to skeletal muscle cells.
2. The protease must have the ability to reproduce postmortem changes in myofibrils in an in-vitro setting under optimum conditions.
3. The protease must access to myofibrils in tissue.

According to Koohmaraie (1996) calpains, or more specifically μ-calpains, are the only proteases that meet all of the above listed criteria.

It is also believed by some researchers that the structural weakening of stromal proteins (connective tissue) during the postmortem aging of meat may also play a role in the tenderization effect seen. According to research conducted by Nishimura et al., (1998) rapid decreases in shear force values were seen up to 10 days postmortem, with gradual decreases seen thereafter. Nishimura et al. (1998) believe that this initial decrease in shear force is due to the structural weakening of myofibrillar proteins, while the final more gradual decrease in shear force is due to the continued weakening of myofibrillar proteins along with the structural weakening of intramuscular connective tissue. Nishimura et al. (1998) demonstrated that the mechanical strength of intramuscular connective remained unchanged for up to 10 days postmortem, but then began to decrease linearly until day 35.

USDA Quality Grade and Palatability

According to Smith et al. (1987) USDA quality grades were originally designed to provide the basis for reporting dressed beef markets. However, USDA quality grades have been amended and evolved over the years in order to try and sort carcasses into groups based on palatability differences according to overall maturity and marbling scores. Unfortunately there has been much conflicting evidence over the years as to exactly how well USDA quality grades can predict cooked beef palatability.

It has been documented that across the entire range of USDA quality grades, USDA Prime (most desirable) to USDA Canner (least desirable), quality grading does an effective job of determining palatability differences between carcasses (Smith et al., 1987). However, among a more narrow range of grades such as USDA Choice, USDA Select, and USDA Standard the lines are not as clearly defined. Dolezal et al. (1982) showed that among USDA Choice, Good (Select), and Standard steaks, USDA Choice steaks generally received higher scores in trained sensory panel evaluations. However the data also showed that overall tenderness and connective tissue amount scores were not significantly different between USDA Choice and USDA Select steaks, while juiciness scores between USDA Select and USDA Standard were also not significantly different. Armbruster et al. (1983) were able to show that marbling, which is the primary determinant of USDA quality grade within A maturity carcasses, is positively associated with flavor and juiciness among Angus cattle. However, they also showed that marbling score explained less than 4% of the variation in flavor, 2% of the variation in juiciness, and 1.2% of the variation in tenderness. Accordingly, cut may also play a substantial role in whether or not quality grade accurately indicates palatability. In a study conducted by Smith et al. (1987) in which both strip loin (longissimus dorsi) samples and round samples (semimembranosus, biceps femoris, and semitendinosus) were evaluated, the researchers determined that USDA quality grades were not useful in determining the palatability of broiled round steaks. It would also be important to consider if some of the aforementioned postmortem treatments aimed at improving palatability can mask tenderness differences due to USDA quality grade.

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CHAPTER III

Consumer and trained sensory evaluation of muscles isolated from the beef chuck and round

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ABSTRACT: Individual beef chuck and round muscles representing various USDA quality grades (Choice, Select, and Standard) were evaluated to assess their potential as a value-added foodservice steak from underutilized beef muscles. Four chuck muscles (infraspinatus, triceps brachii, teres major, and supraspinatus) and four round muscles (rectus femoris, vastus lateralis, biceps femoris, and semimembranosus) were utilized in this study. Individual muscles were trimmed free of visible connective tissue and further processed into 0.2 kg portion sized steaks. Steaks were then subjected to one of two marination treatments (treated or negative control). Treated muscles were mechanically tenderized, twice, using a needle tenderizer, and their steaks were marinated for two, 6-min cycles in a vacuum tumbler utilizing a marinade consisting of water, *Aspergillus oryzae*, and salt. Steaks were then allowed to reach a combined (sub-primal and steak) age of 21 d before further analysis. Steaks were evaluated for sensory characteristics via consumer panel and trained sensory panel. The infraspinatus, rectus femoris, and teres major received the highest ($P < 0.05$) consumer overall acceptability and tenderness ratings, whereas the vastus lateralis had the lowest overall acceptability scores among all

muscles evaluated. The vastus lateralis, biceps femoris, semimembranosus, and supraspinatus received the lowest ($P < 0.05$) tenderness ratings among all steaks evaluated by consumers. Treated steaks from the eight muscles ranked significantly higher for all consumer sensory attributes when compared to their non-treated control ($P < 0.01$). Trained sensory panel evaluations varied greatly by grade and treatment, with a grade by treatment interaction evident for several muscles. Generally, treated steaks received more favorable ratings than their non-treated counterparts for all sensory attributes. Grade effects varied, with USDA Choice muscles receiving higher scores in most instances. For muscles with quality grade by treatment interactions, treated steaks from USDA Choice carcasses generally received the most favorable ratings. These data show that treated USDA Choice steaks, especially those isolated from the infraspinatus, rectus femoris, and teres major, exhibit the most potential for producing palatable steaks based on their overall consumer and sensory panel values.

Key Words: Beef, Muscle, Sensory Evaluation, Consumer Panel, Marination

Introduction

The wholesale beef chuck and round represents a large percentage of a beef carcass on a weight basis. Unfortunately, cuts from the chuck and the round have traditionally been of low value and fabricated into low-priced roasts and ground beef, while cuts from the rib and loin are typically utilized as steaks. The objective of this study was to evaluate the potential for developing palatable steaks from underutilized beef muscles. Four chuck muscles (infraspinatus, triceps brachii, teres major, and supraspinatus) and four round muscles (rectus femoris, vastus lateralis, biceps femoris, and semimembranosus) were identified within three USDA quality grades (Choice, Select, and Standard). Steaks from all three USDA Quality Grades were evaluated by trained sensory panelists, while USDA Choice muscles only were evaluated by consumer panelists to determine treatment and quality grade effects.

Materials and Methods

Sub-primals. Beef chuck and round sub-primals consisting of the shoulder clod, Institutional Meat Purchase Specifications (IMPS) #114 (NAMP, 1997); chuck tender, IMPS #116B (NAMP, 1997); knuckle, IMPS #167A (NAMP, 1997); inside round, IMPS #169A (NAMP, 1997); and outside round, IMPS #171B (NAMP, 1997) were obtained from a federally inspected beef processing plant in Dodge City, Kansas and shipped to the Food and Agricultural Products Center (FAPC) at Oklahoma State University. Sample sizes within each quality grade consisted of: shoulder clod, n = 35; chuck tender, n = 35; knuckle, n = 30; inside round, n = 20; and outside round, n = 20. Upon arrival, the sub-primals were fabricated into individual muscles and completely denuded of fat and visible connective tissue using a Townsend® skinner (Townsend Engineering Co., Des Moines, IA). Individual muscles were then vacuum packaged and stored in a 4°C cooler until transport to National Steak and Poultry (NSP) in Owasso, Oklahoma for further processing.

Fabrication, Marination and Tenderization of Steaks. Muscles were randomly segregated into two groups (a treated group and a control group) to obtain an equal representation of each muscle per treatment. The treated muscles were mechanically tenderized, twice, utilizing a ROSS® needle tenderizer (Ross Industries, Inc., Midland, VA). The treated muscles were then cut into 0.2 kg steaks and marinated for two, 6-min cycles in a vacuum tumbler. The marinade consisted of water, *Aspergillus oryzae* (tenderizer), and salt with an overall absorption of 12% of the original muscle raw weight. The control muscles were fabricated into 0.2 kg steaks and vacuum packaged. All steaks were then individually vacuum-packaged and allowed to reach 21 d of aging (combined age for sub-primal and steak) in a 4°C cooler before being frozen at -30°C. After the samples were completely frozen they were stored at -10°C.

Consumer Panel. The consumer panel evaluations were held on three consecutive evenings, in a restaurant setting, at Taylor Dining (Human Environmental Science Building on the Oklahoma State University Campus). Panelists were recruited by flyers and mailings. Before being served, panelists were asked to answer a series of questions pertaining to their demographic makeup and steak purchasing habits. The panelists were then served a meal consisting of a salad, vegetable, bread, and three unseasoned steak samples, followed by dessert. All steaks were cooked to 70°C (medium degree of doneness) on a commercial flame-broil grill located on site. The steak samples consisted of a treated portion, a non-treated potion of the same muscle, and a portion of untreated Certified Angus Beef® (CAB®) top loin steak that had been aged for 21 days postmortem. Each sample weighed approximately 99 g. Panelists ranked the steaks using a nine-point scale for overall like, flavor, juiciness, tenderness and a five-point scale for purchase intent (overall like and flavor: 1 = extremely dislike, 9 = extremely like; juiciness: 1 = extremely dry, 9 = extremely juicy; tenderness: 1 = extremely tough, 9 = extremely tender; purchase intent: 1 = definitely would not buy, 5 = definitely would buy).

Trained Sensory Panel. Trained sensory panel evaluations took place over an eight-d period. Potential panelists were trained according to American Meat Science Association (1995) guidelines. During sensory analysis, two separate trained panel groups (consisting of six to eight panelists) evaluated samples twice daily. Panelists were asked to evaluate samples for tenderness, juiciness, connective tissue amount, and overall acceptability using an eight-point scale, and uncharacteristic flavor using a four-point scale (tenderness: 1 = extremely tough, 8 = extremely tender; juiciness: 1= extremely dry, 8 = extremely juicy; connective tissue amount: 1 = abundant, 8 = none; overall acceptability: 1 = extremely undesirable, 8 = extremely desirable; uncharacteristic flavor: 1 = extremely uncharacteristic, 4 = none). Steaks were cooked to an internal temperature of 70°C on a flame-broil grill (Model RB-846-C, Rankin Inc., Whittier, CA). The evaluations took place at the FAPC sensory test room in individual sensory booths under red lights. Panelists were given unsalted crackers and water to cleanse their pallets between each sample.

Statistics. Trained sensory panel data were blocked by muscle and analyzed using least squares analysis of variance (PROC GLM; SAS Institute, Cary, NC). The model included treatment, quality grade, and interactions to evaluate their effect on sensory attributes. Means were separated using least significant difference. Consumer panel data were analyzed using least squares analysis of variance (PROC GLM; SAS Institute, Cary, NC). Model included muscle and treatment to evaluate their effect on sensory attributes. Means were separated using least significant difference.

Results and Discussion

Consumer Panel

Consumer panel demographic information is presented in Tables 1 and 2. Least squares means for consumer panel responses, excluding CAB® steaks, are presented in Table 3. Steaks fabricated from the infraspinatus, rectus femoris, and teres major received the highest ($P < 0.01$) overall acceptability and tenderness ratings, whereas the vastus lateralis had the lowest overall acceptability scores among all muscles evaluated. Tenderness data for the infraspinatus are consistent with the findings of Cecchi et al. (1988); Patterson and Parrish (1986); McKeith et al. (1985); and Ramsbottom and Strandine (1948) which showed the infraspinatus to be the most tender chuck muscle evaluated in each study by shear force and/or trained sensory panel. The vastus lateralis, biceps femoris, semimembranosus, and supraspinatus received the lowest ($P < 0.01$) tenderness ratings among all steaks evaluated by consumers. Steaks from the infraspinatus, teres major, biceps femoris, and rectus femoris each received mean flavor scores of 6 or higher indicating "slightly like", with the infraspinatus receiving the highest scores of all muscles sampled ($P < 0.05$). However, mean flavor scores for the teres major, biceps femoris, and rectus femoris were not significantly different from those received by the triceps brachii, semimembranosus, and supraspinatus, which all received scores indicating "neither like nor dislike". Steaks from the infraspinatus received the highest juiciness scores while steaks from the vastus lateralis received the lowest. Juiciness scores among the remaining muscles were not significantly different. Purchase intent scores were highest ($P < 0.01$) for infraspinatus steaks, whereas the vastus lateralis, triceps brachii, and biceps femoris steaks received the lowest purchase intent scores by consumers.

The effect of treatment on consumer evaluations is presented in Table 4. Treated steaks from the eight muscles ranked significantly higher ($P < 0.01$) for all consumer evaluated traits when compared to their non-treated controls. These data support previous research, which indicates mechanical tenderization improves tenderness by lowering shear force values and improving trained sensory panel ratings (Jeremiah et al., 1999; Pringle et al., 1998; Glover et al., 1977; Savell et al., 1977). Howat et al. (1983) reported that marination also improved the tenderness of semimembranosus steaks by lowering shear force values and improving trained sensory panel ratings. Previous research also indicates that mechanical tenderization can also improve other sensory panel attributes of certain muscles. Jeremiah et al. (1999) reported that mechanical tenderization improved the flavor desirability and overall palatability of certain round muscles, while Pringle et al. (1998) reported that mechanical tenderization also improved the overall palatability scores of top sirloin steaks. These data contradict previous research, which suggests mechanical tenderization could lower the juiciness of steaks (Jeremiah et al., 1999; Pringle et al., 1998; Savell et al., 1977). However, the improvement of juiciness scores in this study could potentially be attributed to marination.

Differences in consumer responses among treated muscles and non-treated CAB® steaks are presented in Table 5. Treated infraspinatus steaks significantly outperformed ($P < 0.05$) CAB® steaks in all sensory categories evaluated. All other treated muscles received scores that were not significantly different from non-treated CAB® steaks, excluding the vastus lateralis which received juiciness and tenderness scores that were significantly lower ($P < 0.05$) than non-treated CAB® steaks. These data indicated that blade tenderization and marination of the muscles evaluated in this study results in consumer satisfaction equal to that of CAB® top loin steaks aged for 21 d.

Trained Sensory Panel

Trained sensory panel evaluations varied greatly by grade and treatment, with a grade by treatment interaction evident for several muscles. Generally, treated steaks received more favorable rating than their non-treated counterparts for all sensory attributes. Grade effects varied, with USDA Choice muscles receiving higher scores in most instances. For muscles with quality grade by treatment interactions, treated steaks from USDA Choice carcasses generally received the most favorable ratings.

Sensory tenderness scores for each muscle and treatment are presented in Table 6. Biceps femoris steaks had a significant treatment effect for tenderness with treated steaks receiving a "slightly tender" rating. Teres major steaks had a significant grade effect for tenderness, with USDA Standard steaks receiving higher ratings than USDA Select steaks. Infraspinatus, rectus femoris, semimembranosus, supraspinatus, triceps brachii, and vastus lateralis steaks had a grade by treatment interaction for tenderness. USDA Standard, non-treated infraspinatus steaks received the highest tenderness ratings, which were similar to scores for USDA Select, treated steaks. Panel scores were significantly lower for USDA Choice, control steaks which were statistically similar to USDA Select, control infraspinatus steaks. Among rectus femoris muscles, USDA Choice treated steaks were rated highest by trained panelists, with no differences in panel scores existing for the remaining grade and treatment combinations. Non-treated USDA Choice, Select, and Standard semimembranosus and triceps brachii steaks, as well as, non-treated USDA Choice supraspinatus and vastus lateralis steaks were ranked as "slightly tough" by panelists. All other muscles with a grade by treatment interaction received a mean tenderness rating of "slightly" or "moderately tender".

Sensory panel scores for juiciness are presented in Table 7. Treated supraspinatus steaks were juicier than their non-treated counterparts. A USDA quality grade effect on juiciness scores was evident for the rectus femoris and teres major. USDA Choice and Select rectus femoris steaks were juicier than USDA Standard steaks. USDA Select and Standard teres major steaks were significantly drier than their USDA Choice counterpart. Among steaks with a significant grade by treatment interaction for juiciness, treated USDA Choice and Standard steaks, excluding the biceps femoris, received the highest ($P < 0.05$) mean juiciness scores.

Trained sensory panel scores for uncharacteristic flavor are presented in Table 8. USDA quality grade and treatment had no effect on the flavor scores of the infraspinatus and vastus lateralis. Treated semimembranosus and teres major steaks received more favorable ratings than their non-treated counterparts. USDA Standard biceps femoris and rectus femoris steaks had significantly more desirable scores than their USDA Choice counterparts. While significant differences exist among data for uncharacteristic flavor, the mean score for all muscles was 3, indicating a "slight" amount of uncharacteristic flavor. Frequency data among treated and non-treated steaks revealed that 74% of biceps femoris, infraspinatus, and rectus femoris steaks received flavor scores of "no uncharacteristic flavor", while 71% of semimembranosus steaks, 66% of supraspinatus steaks, 70% of triceps brachii steaks, 76% of teres major steaks, and 67% of vastus lateralis steaks also received flavor scores of "no uncharacteristic flavor".

Connective tissue amount, as rated by trained panelists, is presented in Table 9. Among those steaks with a significant treatment effect for connective tissue amount, treated steaks received higher mean scores, indicating lower amounts of detectable connective tissue. These findings are supported by previous research that indicates mechanical tenderization lowers the amount of detectible connective tissue perceived by trained sensory panelists (Jeremiah et al., 1999; Pringle et al., 1998; Savell et al., 1977). Detectible connective tissue amounts could also potentially be lowered by the use of *Aspergillus oryzae*. Among those steaks with a significant grade effect, USDA Choice and Standard received more favorable scores than steaks from USDA Select. Responses varied greatly among muscles with a significant grade by treatment interaction for connective tissue. Nevertheless, infraspinatus steaks received the highest ratings while supraspinatus steaks received the lowest ratings among muscles with a significant grade by treatment interaction.

Overall acceptance scores, as determined by sensory analysis, are present in Table 10. Semimembranosus steaks had both a significant grade and treatment effect for overall acceptability. Treatment greatly improved mean acceptability scores for semimembranosus steaks from "slightly undesirable" to "slightly desirable". These data are supported by the findings of Jeremiah et al. (1999), which showed that mechanical tenderization improved the overall palatability of scores of inside round muscles. USDA Choice semimembranosus steaks were rated higher ($P < 0.05$) than USDA Standard steaks and similar to USDA Select steaks. Among steaks with a significant grade by treatment interaction for overall acceptability, all infraspinatus and teres major steaks received a mean score of "slightly desirable" or higher. Other muscles varied greatly by treatment and grade. The triceps brachii received a mean score of "undesirable" for USDA Select non-treated steaks, and a mean score of "desirable" for USDA Choice treated steaks.

Implications

While more research is needed to explore consumer and industry acceptance of these muscles, data show several muscles have potential as foodservice steaks. These data suggest that treated USDA Choice steaks, especially those isolated from the infraspinatus, rectus femoris, and teres major, exhibit the most potential for producing palatable value-added steaks, based on consumer and sensory values. Ultimately the value of these muscles will be based on processors willingness to isolate these muscles. Labor cost, trim losses, and purge are factors which must be considered, along with the palatability ratings and shear force values, to determine which muscles can successfully add value to the beef carcass.

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Table 1. Demographic data: gender, age, employment, education, and household size of consumer panelist in the study

Item	n	%
Gender[1]		
Male	88	49.16
Female	91	50.84
Age[2]		
<20	6	3.35
20-29	45	25.14
30-39	33	18.44
40-49	38	21.23
50-59	41	22.91
>60	16	8.94
Employment[3]		
Student	17	9.50
Not employed	10	5.59
Part-time	12	6.70
Full-time	131	73.18
Other	9	5.03
Education[4]		
High school	44	24.58
College/university	81	45.25
Graduate school	54	30.17
Household size[5]		
1	17	9.50
2	84	46.93
3	37	20.67
4	37	20.67
5	3	1.68
>6	1	0.56

[1]Please indicate your gender.
[2]Please indicate your age by marking the appropriate blank.
[3]Please indicate your current working status by marking the appropriate blank.
[4]Please indicate your highest level of education.
[5]Please indicate your household size, including yourself.

Table 2. Demographic data: steak consumption, foodservice establishment type normally visited, USDA quality grade eaten most, quality grade listed, degree of doneness, steak preparation and/or seasoning preferences of consumer panelist in the study

Item	n	%
Steak consumption[1]		
<1 time / month	53	29.94
1-2 times / month	58	32.77
2-4 times / month	44	24.86
1-2 times / week	17	9.60
2-4 times / week	5	2.82
Foodservice establishment[2]		
Fast food chain	48	27.12
Family restaurant chain	19	10.73
Casual restaurant chain	61	34.46
Cafeteria	3	1.69
Ethnic	40	22.60
Fine Dining	3	1.69
Bakery	3	1.69
USDA quality grade eaten[3]		
Don't know	83	46.89
Prime	25	14.12
Choice	48	27.12
Certified Angus beef	19	10.73
Other	2	1.13
Quality grade importance[4]		
No	125	69.83
Yes	54	30.17
Degree of doneness[5]		
Rare	7	3.91
Medium rare	58	32.40
Medium	53	29.61
Medium well	49	27.37
Well done	10	5.59
Very well done	2	1.12
Seasoning preferences[6]		
Plain	23	12.85
Seasoned	70	39.11
Marinated	63	35.20
With butter	3	1.68
With sauce	20	11.17

[1]Please indicate how often you consume steak in/from a foodservice establishment.
[2]From which one type of foodservice establishment do you purchase food most often?
[3]What USDA quality grade are the steaks that you most often eat from a foodservice establishment?
[4]Do you go out of your way to eat steak in/from an establishment that offers a specific quality grade?
[5]What degree of doneness do you usually request your steak be prepared to in foodservice establishments?
[6]How do you prefer to eat your steak from a foodservice establishment?

Table 3. Least squares means for consumer responses by muscle

Item	Triceps brachii	Infraspinatus	Teres major	Biceps femoris	Semimembranosus	Vastus lateralis	Rectus femoris	Supraspinatus
Overall[f]	5.7^{b}	7.0^{c}	6.1^{bc}	5.6^{b}	5.7^{b}	4.8^{a}	6.4^{bc}	6.0^{b}
Flavor[g]	5.5^{ab}	6.7^{c}	6.0^{bc}	6.0^{bc}	5.5^{ab}	5.1^{a}	6.2^{bc}	5.9^{b}
Juiciness[h]	5.6^{b}	7.0^{c}	5.6^{b}	5.8^{b}	5.6^{b}	4.3^{a}	5.7^{b}	5.9^{b}
Tenderness[i]	5.7^{bcd}	7.1^{e}	6.3^{cde}	5.3^{ab}	5.2^{ab}	4.8^{a}	6.4^{de}	5.6^{abc}
Purchase[j]	3.0^{ab}	3.8^{c}	3.2^{b}	3.0^{ab}	3.0^{b}	2.6^{a}	3.4^{bc}	3.1^{b}

[a,b,c,d,e]Within a row means without a common superscript letter differ ($P < 0.01$)

[f]Overall: 4 = slightly dislike: 5 = neither like nor dislike; 6 = slightly like; 7 = like

[g]Flavor: 5 = neither like nor dislike; 6 = slightly like

[h]Juiciness: 4 = moderately dry; 5 = slightly dry / slightly juicy; 6 = moderately juicy; 7 = very juicy

[i]Tenderness: 4 = moderately tough; 5 = slightly tough slightly tender; 6 = moderately tender; 7 = very tender

[j]Purchase: 2 = Probably would not buy if this steak were offered on foodservice menu; 3 = Might or might not buy if this steak were offered on a foodservice menu

Table 4. Least squares means for consumer responses of all muscles by treatment

Item	Control	Treated
Overall[c]	5.2[a]	6.6[b]
Flavor[d]	5.2[a]	6.6[b]
Juiciness[e]	5.1[a]	6.3[b]
Tenderness[f]	5.0[a]	6.6[b]
Purchase[g]	2.7[a]	3.5[b]

[a,b]Within a row means without a common superscript letter differ ($P < 0.01$)
[c]Overall: 5 = neither like nor dislike; 6 = slightly like
[d]Flavor: 5 = neither like nor dislike; 6 = slightly like
[e]Juiciness: 5 = slightly dry / slightly juicy; 6 = moderately juicy
[f]Tenderness: 5 = slightly tough / slightly tender; 6 = moderately tender
[g]Purchase: 2 = Probably would not buy if this steak were offered on foodservice menu; 3 = Might or might not buy if this steak were offered on a foodservice menu

Table 5. Least squares means of consumer responses for treated muscles including non-treated Certified Angus Beef

	Sensory Characteristic				
Muscle	Overall[e]	Flavor[f]	Juiciness[g]	Tenderness[h]	Purchase[i]
Triceps brachii	6.9[bc]	6.5[ab]	6.7[bc]	6.7[bcd]	3.5[a]
Infraspinatus	7.6[c]	7.4[b]	7.7[c]	7.7[d]	4.2[b]
Teres major	6.3[ab]	6.5[ab]	5.8[ab]	6.7[bcd]	3.4[a]
Biceps femoris	6.4[ab]	6.7[ab]	6.4[b]	5.7[ab]	3.5[a]
Semimembranosus	6.7[bc]	6.4[a]	6.4[b]	6.5[abc]	3.7[ab]
Vastus lateralis	5.6[a]	6.1[a]	4.6[a]	5.6[a]	3.1[a]
Rectus femoris	6.8[bc]	6.6[ab]	6.4[b]	7.5[cd]	3.7[ab]
Supraspinatus	6.6[b]	6.4[a]	6.2[b]	6.2[ab]	3.3[a]
Certified Angus Beef	6.4[ab]	6.4[a]	6.4[b]	6.5[bc]	3.5[a]

[a,b,c,d]Within a column means without a common superscript letter differ ($P < 0.05$)
[e]Overall: 5 = neither like nor dislike; 6 = slightly like; 7 = like
[f]Flavor: 6 = slightly like; 7 = like
[g]Juiciness: 5 = slightly dry / slightly juicy; 6 = moderately juicy; 7 = juicy
[h]Tenderness: 5 = slightly tough / slightly tender; 6 = moderately tender; 7 = tender
[i]Purchase: 2 = Probably would not buy if this steak were offered on foodservice menu; 3 = Might or might not buy if this steak were offered on a foodservice menu; 4 = Probably would buy if this steak were offered on a foodservice menu

Table 6. Main effect and treatment interaction least squares means for trained sensory tenderness scores[e]

	Treatment		USDA Grade			Interaction					
Muscle	Control	Treated	Ch[1]	Se[2]	St[3]	Ch:Control	Ch:Treated	Se:Control	Se:Treated	St:Control	St:Treated
Biceps femoris	4.9^{a}	5.6^{b}	ns	ns	ns	ns	ns	ns	ns	ns	ns
Infraspinatus	-	-	-	-	-	6.0^{a}	6.4^{bc}	6.1^{ab}	6.7^{cd}	6.8^{d}	6.4^{bc}
Rectus femoris	-	-	-	-	-	5.6^{a}	6.4^{b}	5.8^{a}	5.6^{a}	5.7^{a}	5.5^{a}
Semimembranosus	-	-	-	-	-	4.7^{a}	6.3^{c}	4.8^{a}	5.3^{b}	4.7^{a}	5.5^{b}
Supraspinatus	-	-	-	-	-	4.5^{a}	5.5^{b}	5.4^{b}	5.5^{b}	5.1^{b}	5.3^{b}
Teres major	ns	ns	6.2^{ab}	6.0^{a}	6.4^{b}	ns	ns	ns	ns	ns	ns
Triceps brachii	-	-	-	-	-	4.4^{ab}	6.4^{d}	4.0^{a}	5.4^{c}	4.8^{b}	6.0^{d}
Vastus lateralis	-	-	-	-	-	4.8^{a}	5.8^{b}	5.0^{a}	5.2^{a}	5.0^{a}	6.3^{c}

[a,b,c,d]Within a row means without a common superscript letter differ ($P < 0.05$)

[e]Tenderness: 4 = slightly tough; 5 = slightly tender; 6 = moderately tender.

[1]Ch = USDA Choice; [2]Se = USDA Select; [3]St = USDA Standard

ns = not significant

Table 7. Main effect and treatment interaction least squares means for trained sensory juiciness scores[e]

	Treatment		USDA Grade			Interaction					
Muscle	Control	Treated	Ch[1]	Se[2]	St[3]	Ch:Control	Ch:Treated	Se:Control	Se:Treated	St:Control	St:Treated
Biceps femoris	-	-	-	-	-	4.4^{a}	6.0^{c}	5.4^{b}	5.7^{bc}	4.6^{a}	5.3^{b}
Infraspinatus	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Rectus femoris	ns	ns	5.9^{a}	5.6^{a}	4.7^{b}	ns	ns	ns	ns	ns	ns
Semimembranosus	-	-	-	-	-	4.6^{a}	5.4^{b}	4.7^{a}	4.6^{a}	4.5^{a}	5.7^{b}
Supraspinatus	4.8^{a}	5.3^{b}	ns	ns	ns	ns	ns	ns	ns	ns	ns
Teres major	ns	ns	6.1^{a}	5.8^{b}	5.7^{b}	ns	ns	ns	ns	ns	ns
Triceps brachii	-	-	-	-	-	4.1^{a}	5.8^{d}	4.6^{b}	5.4^{c}	4.6^{b}	5.4^{cd}
Vastus lateralis	-	-	-	-	-	5.2^{ab}	5.9^{c}	5.5^{b}	5.4^{b}	4.9^{a}	6.0^{c}

[a,b,c,d]Within a row means without a common superscript letter differ ($P < 0.05$)

[e]Juiciness: 4 = slightly dry; 5 = slightly juicy; 6 = moderately juicy.

[1]Ch = USDA Choice; [2]Se = USDA Select; [3]St = USDA Standard

ns = not significant

Table 8. Main effect and treatment interaction least squares means for trained sensory uncharacteristic flavor scores[c]

	Treatment		USDA Grade			Interaction					
Muscle	Control	Treated	Ch[1]	Se[2]	St[3]	Ch:Control	Ch:Treated	Se:Control	Se:Treated	St:Control	St:Treated
Biceps femoris	ns	ns	3.6[a]	3.7[b]	3.8[b]	ns	ns	ns	ns	ns	ns
Infraspinatus	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Rectus femoris	ns	ns	3.6[a]	3.7[ab]	3.8[b]	ns	ns	ns	ns	ns	ns
Semimembranosus	3.5[a]	3.7[b]	ns	ns	ns	ns	ns	ns	ns	ns	ns
Supraspinatus	-	-	-	-	-	3.2[a]	3.8[b]	3.7[b]	3.7[b]	3.6[b]	3.6[b]
Teres major	3.6[a]	3.8[b]	ns	ns	ns	ns	ns	ns	ns	ns	ns
Triceps brachii	-	-	-	-	-	3.5[a]	3.8[b]	3.6[a]	3.6[ab]	3.8[b]	3.5[a]
Vastus lateralis	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

[a,b]Within a row means without a common superscript letter differ ($P < 0.05$)

[c]Uncharacteristic flavor: 3 = slight.

[1]Ch = USDA Choice; [2]Se = USDA Select; [3]St = USDA Standard

ns = not significant

Table 9. Main effect and treatment interaction least squares means for trained sensory connective tissue amount scores^{e}

	Treatment		USDA Grade			Interaction					
Muscle	Control	Treated	Ch[1]	Se[2]	St[3]	Ch:Control	Ch:Treated	Se:Control	Se:Treated	St:Control	St:Treated
Biceps femoris	4.7^{a}	5.0^{b}	ns	ns	ns	ns	ns	ns	ns	ns	ns
Infraspinatus	-	-	-	-	-	5.6^{a}	6.0^{abc}	5.7^{a}	6.4^{c}	6.3^{bc}	5.9^{ab}
Rectus femoris	-	-	-	-	-	5.2^{a}	6.2^{c}	5.6^{ab}	5.2^{a}	5.8^{bc}	5.4^{ab}
Semimembranosus	5.0^{a}	5.5^{b}	ns	ns	ns	ns	ns	ns	ns	ns	ns
Supraspinatus	-	-	-	-	-	4.6^{a}	5.5^{d}	5.1^{bcd}	5.4^{cd}	4.9^{abc}	4.8^{ab}
Teres major	-	-	-	-	-	6.1^{bc}	5.6^{ab}	5.7^{ab}	5.8^{abc}	5.6^{a}	6.2^{c}
Triceps brachii	4.6^{a}	5.6^{b}	5.4^{a}	4.7^{b}	5.3^{a}	ns	ns	ns	ns	ns	ns
Vastus lateralis	4.9^{a}	5.4^{b}	5.1^{ab}	4.9^{a}	5.4^{b}	ns	ns	ns	ns	ns	ns

^{a,b,c,d}Within a row means without a common superscript letter differ ($P < 0.05$)

^{e}Connective tissue amount: 4 = moderate; 5 = slight; 6 = traces.

[1]Ch = USDA Choice; [2]Se = USDA Select; [3]St = USDA Standard

ns = not significant

Table 10. Main effect and treatment interaction least squares means for trained sensory overall acceptability^{c}

Muscle	Treatment		USDA Grade			Interaction					
	Control	Treated	Ch[1]	Se[2]	St[3]	Ch:Control	Ch:Treated	Se:Control	Se:Treated	St:Control	St:Treated
Biceps femoris	-	-	-	-	-	4.0^{a}	5.2^{c}	4.6^{b}	4.9^{bc}	4.0^{a}	5.0^{bc}
Infraspinatus	-	-	-	-	-	5.6^{a}	5.8^{ab}	5.6^{a}	6.4^{c}	6.3^{bc}	5.7^{a}
Rectus femoris	-	-	-	-	-	4.9^{a}	5.8^{b}	5.2^{a}	4.9^{a}	4.8^{a}	4.9^{a}
Semimembranosus	4.2^{a}	5.1^{b}	4.9^{a}	4.6^{ab}	4.4^{b}	ns	ns	ns	ns	ns	ns
Supraspinatus	-	-	-	-	-	3.9^{a}	5.3^{c}	4.7^{b}	5.0^{bc}	4.6^{b}	4.6^{b}
Teres major	-	-	-	-	-	5.9^{cd}	5.8^{bcd}	5.1^{a}	5.7^{bc}	5.4^{ab}	6.1^{d}
Triceps brachii	-	-	-	-	-	4.4^{b}	6.0^{d}	3.9^{a}	5.2^{c}	4.6^{b}	5.3^{c}
Vastus lateralis	-	-	-	-	-	4.3^{a}	5.3^{b}	4.6^{a}	4.8^{a}	4.5^{a}	5.6^{b}

^{a,b,c,d}Within a row means without a common superscript letter differ ($P < 0.05$)

^{c}Overall acceptability: 3 = undesirable; 4 = slightly undesirable; 5 = slightly desirable; 6 = desirable.

[1]Ch = USDA Choice; [2]Se = USDA Select; [3]St = USDA Standard

ns = not significant

CHAPTER IV

Shear force determination and yield data of muscles isolated from the beef chuck and round

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ABSTRACT: Four chuck muscles and four round muscles representing various USDA quality grades were evaluated to assess their potential as a value-added foodservice steak from underutilized beef muscles. Individual muscles were trimmed free of visible connective tissue and further processed into 0.2 kg portion sized steaks. Steaks were then subjected to one of two marination treatments. Treated muscles were mechanically tenderized, twice, using a needle tenderizer, and their steaks were marinated for two, 6-min cycles in a vacuum tumbler utilizing a marinade consisting of water, *Aspergillus oryzae*, and salt. Steaks were then allowed to reach a combined (sub-primal and steak) age of 21 d before further analysis. Fabrication time and yield data were collected for both sub-primals and steaks, and steaks were evaluated for tenderness differences via Warner-Bratzler shear force determination. Among steaks with a significant main effect for treatment, treated steaks had the lowest shear force values ($P < 0.05$). Among steaks with a significant grade effect, USDA Choice infraspinatus, triceps brachii, and biceps femoris had the lowest shear force values ($P < 0.01$). The rectus femoris and teres major muscles had a significant grade by treatment interaction for Warner-Bratzler shear force.

Treated USDA Standard and Choice rectus femoris and teres major steaks exhibited the lowest ($P < 0.01$) shear force values. Finally, neither treatment nor USDA quality grade had an effect on supraspinatus Warner-Bratzler shear force values. The supraspinatus had the highest yields of all sub-primals sampled. The denuded muscle yields of all muscles from the shoulder clod were markedly lower when compared to other sub-primals. The semimembranosus produced the highest mean number of 0.2 kg steaks, as well as, the highest percentage yield of steaks. The teres major produced the lowest mean number of 0.2 kg steaks, while the triceps brachii had the lowest percent yield of steaks. Sub-primal fabrication time varied, with the shoulder clod generally taking the longest to fabricate. The biceps femoris and semimembranosus took the longest time to fabricate into steaks, but produced the highest number of 0.2 kg steaks. These data suggest that treated USDA Choice steaks, especially those isolated from the infraspinatus, rectus femoris, and teres major, exhibit the most potential for producing palatable steaks based on their overall shear force values.

Key Words: Beef, Muscle, Shear Force, Yield, Marination

Introduction

The weight of the wholesale beef chuck and round represents over fifty percent of beef carcass weight. Unfortunately, cuts from the chuck and the round have traditionally been of low value and fabricated into low-priced roasts, steak or ground beef. The objective of this study was to evaluate the potential for developing palatable steaks from underutilized beef muscles. Four chuck muscles (infraspinatus, triceps brachii, teres major, and supraspinatus) and four round muscles (rectus femoris, vastus lateralis, biceps femoris, and semimembranosus) were identified. USDA quality grades (Choice, Select, and Standard) were sampled to determine the effect of mechanical tenderization and marination on the Warner-Bratzler shear force of steaks produced from individual muscles coming from the chuck and the round. Fabrication times and yield data of steaks produced from these muscles were also evaluated.

Materials and Methods

Sub-primals. Beef chuck and round sub-primals consisting of the shoulder clod, Institutional Meat Purchase Specifications (IMPS) #114 (NAMP, 1997); chuck tender, IMPS #116B (NAMP, 1997); knuckle, IMPS #167A (NAMP, 1997); inside round, IMPS #169A (NAMP, 1997); and outside round, IMPS #171B (NAMP, 1997) were obtained from a federally inspected beef processing plant in Dodge City, Kansas and shipped to the Food and Agricultural Products Center (FAPC) at Oklahoma State University. Sample sizes within each quality grade consisted of: shoulder clod, n = 35 per grade; chuck tender, n = 35 per grade; knuckle, n = 30 per grade; inside round, n = 20 per grade; and outside round, n = 20 per grade. Upon arrival, the sub-primals were fabricated into individual muscles and completely denuded of fat and connective tissue using a Townsend® skinner (Townsend Engineering Co., Des Moines, IA). Fabrication time and yield data, including purge loss, were collected. Individual muscles were then vacuum packaged and stored in a 4°C cooler until transport to National Steak and Poultry (NSP) in Owasso, Oklahoma for further processing.

Fabrication, Marination and Tenderization of Steaks. Muscles were randomly segregated into two groups (a treated group and a control group) to obtain an equal representation of each muscle and grade per treatment. The control muscles were fabricated into 0.2 kg steaks by expert cutters at NSP, and fabrication time and yield data were collected. Treated muscles were mechanically tenderized, twice, utilizing a ROSS® needle tenderizer (Ross Industries, Inc., Midland, VA). The treated muscles were then cut into 0.2 kg steaks by expert cutters and marinated for two, 6-min cycles in a vacuum tumbler. The marinade consisted of water, *Aspergillus oryzae* (tenderizer), and salt with an overall absorption of 12% of the original muscle raw weight. All steaks were then individually vacuum-packaged and allowed to reach 21 d of aging (combined age for sub-primal and steak) in a 4ºC cooler before being frozen at -30°C. After the samples were completely frozen they were stored at -10ºC.

Shear Force Determination. Warner-Bratzler shear force was evaluated for all muscles, grades, and treatment groups. Thawed, 0.2 kg steaks were cooked to an internal temperature of 70°C on a flame-broil grill (Model RB-846-C, Rankin Inc., Whittier, CA) within the FAPC. Samples were then allowed to cool to room temperature (26ºC) before coring and shearing. 1.27 cm cores (approximately six per sample) were taken parallel to the muscle fiber and then sheared perpendicular to the muscle fiber orientation on a Universal Instron Testing Machine with a Warner-Bratzler head attachment. The Instron utilized a crosshead speed of 200 mm/min with a static load cell of 1 kN.

Statistics. Shear force data were blocked by muscle and analyzed using least squares analysis of variance (PROC GLM; SAS Institute, Cary, NC). The model included treatment, quality grade, and interactions to evaluate their effect on shear force. Means were separated using least significant difference. Yield data were summarized using simple statistical parameters. Means, standard deviations, minimum values and maximum values were generated using SAS procedures (version 8.2, SAS Institute, Cary, NC).

Results and Discussion

Shear Force

Least squares means and standard errors for Warner-Bratzler shear force values of steaks with a significant main effect for treatment are presented in Table 11. Among these steaks, treated steaks had the lowest shear force values, indicating improved tenderness. These results are consistent with data reported by Glover et al. (1977) and Savell el al. (1977), which showed that mechanical tenderization lowered shear force values. Data reported by Howat et al. (1983) also supports these findings by showing that marination also lowers shear force values. Treated steaks from both the semimembranosus and triceps brachii had mean shear force values of less than 4.6 kg and 3.9 kg, respectively. This indicates that these steaks should have a 50% and 68% chance, respectively, of being rated as "slightly tender" or higher by trained sensory panelists according to tenderness threshold values reported by Shackelford et al. (1991). While values of less than or equal to 3.9 kg are considered acceptable, mean shear force values obtained in this study are slightly higher than values for clod and top round steaks reported in the National Beef Tenderness Survey-1998 (Brooks et al., 2000).

The biceps femoris, infraspinatus, and triceps brachii showed a significant main effect for USDA quality grade. Least squares means and standard errors for Warner-Bratzler shear force values of these muscles are presented in Table 12. Among these muscles, USDA Choice steaks showed the lowest shear force values, while there was no significant difference for Warner-Bratzler shear force between USDA Select and USDA Standard steaks, within a muscle. Steaks isolated from the infraspinatus and triceps brachii had mean shear force values below the threshold of 4.6 kg, regardless of USDA quality grade, while biceps femoris steaks had shear force values well above 4.6 kg. Infraspinatus steaks had the lowest mean shear force values of all muscles sampled, with values ranging from 2.68 kg for USDA Choice to 2.98 kg for USDA Standard. Tenderness data for the infraspinatus are consistent with the findings of Cecchi et al. (1988); Patterson and Parrish (1986); McKeith et al. (1985); and Ramsbottom and Strandine (1948) which all showed the infraspinatus to have the lowest shear force values of the chuck muscle evaluated in each study. Accordingly, as reported by Miller et al. (1998), shear force values of less than 3.0 kg should result in 100% consumer satisfaction for tenderness.

Least squares means and standard errors for Warner-Bratzler shear force values of muscles with a significant grade by treatment interaction are presented in Table 13. USDA Standard and Choice steaks from treated rectus femoris and teres major muscles exhibited the lowest ($P < 0.01$) shear force values. All mean values, excluding USDA Choice non-treated teres major, had a shear force value of less than 4.6 kg, while all treated muscles had a shear force value of less than 3.9 kg.

Least squares means and standard errors for Warner-Bratzler shear force values of the supraspinatus are presented in Table 14. Neither treatment nor USDA quality grade had a significant effect on supraspinatus shear force values. Mean shear force values for the supraspinatus ranged from 4.35 kg for treated- USDA Choice steaks, to 5.01 kg for treated-USDA Standard steaks.

Yield

Tables 15 and 16 show the percentage yield and purge loss data of the sub-primals and muscles sampled, by USDA grade. For sub-primal yield and purge data, USDA

Standard products were commodity trimmed, whereas USDA Choice and Select products were closely (6.35 mm) trimmed. Tables 17 through 19 show steak yield data and fabrication times for both sub-primals and steaks. The supraspinatus had the highest yields of all sub-primals sampled (Table 16). While shear force data suggest that the infraspinatus and teres major performed very well, these muscles represent a relatively small portion of the shoulder clod. According to Johnson et al. (1988) the infraspinatus represents approximately 5.8% of the chuck while the teres major represents only approximately 1.2%. The denuded muscle yields of all muscles from the shoulder clod were also markedly lower when compared to other sub-primals. (Table 16). Purge loss varied among the muscles sampled with mean values approaching 0.21 kg for the semimembranosus and supraspinatus. Purge loss values this high could represent a substantial loss in value.

The semimembranosus produced the highest mean number of 0.2 kg steaks, as well as, the highest percent yield of steaks. The teres major produced the lowest mean number of 0.2 kg steaks. The triceps brachii had the lowest percent yield of steaks (Table 17).

Sub-primal fabrication time varied, with the shoulder clod generally taking the longest to fabricate (Table 18). The biceps femoris and semimembranosus took the longest time to fabricate into 0.2 kg steaks (Table 19), but produced the highest number of 0.2 kg steaks. Biceps femoris, triceps brachii, infraspinatus, and semimembranosus muscles proved to be the most labor-intensive muscles to fabricate for steak cutters, while teres major steaks had the shortest steak fabrication times. It should also be noted that the infraspinatus was one of the lowest yielding, most labor-intensive muscles to fabricate. However, the infraspinatus proved to be the most tender muscle sampled. Industry leaders will need to determine if sub-primal yields, steak numbers, and fabrication times warrant fabrication of steaks from these sub-primals.

Implications

While more research is needed to explore consumer and industry acceptance of these muscles, data show several muscles have potential as foodservice steaks. These data suggest that treated USDA Choice steaks, especially those isolated from the infraspinatus, rectus femoris, and teres major, exhibit the most potential for producing palatable value-added steaks, based on their overall shear force values. These data also show that while some muscles from the round can produce large quantities of steaks with high percent yields, there are indications that other muscles may be more palatable. This project has focused on evaluating the potential of eight underutilized cuts for foodservice. However, one must realize that the beef industry must serve many markets. Muscles that do not perform well as enhanced foodservice steaks, might do exceptionally well in pre-cooked entrees where palatability can be enhanced further through processing and cooking.

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Table 11. Least squares means and standard errors for Warner-Bratzler shear values (kg) of steaks from muscles with a significant main effect for treatment

	Treatment	
Muscle	Control	Treated
Semimembranosus	$4.98^{a} \pm 0.09$	$4.55^{b} \pm 0.09$
Triceps brachii	$4.44^{a} \pm 0.06$	$3.61^{b} \pm 0.06$
Vastus lateralis	$5.22^{a} \pm 0.08$	$4.80^{b} \pm 0.08$

[a,b]Within a row means without a common superscript letter differ ($P < 0.01$)

Table 12. Least squares means and standard errors for Warner-Bratzler shear values (kg) of steaks from muscles with a significant main effect for USDA quality grade

	USDA Quality Grade		
Muscle	Choice	Select	Standard
Biceps femoris	$5.24^{a} \pm 0.19$	$6.03^{b} \pm 0.19$	$6.12^{b} \pm 0.19$
Infraspinatus	$2.68^{a} \pm 0.06$	$2.88^{b} \pm 0.06$	$2.98^{b} \pm 0.06$
Triceps brachii	$3.60^{a} \pm 0.07$	$4.26^{b} \pm 0.07$	$4.22^{b} \pm 0.07$

[a,b]Within a row means without a common superscript letter differ ($P < 0.01$)

Table 13. Least squares means and standard errors for Warner-Bratzler shear values (kg) of steaks with a grade x treatment interaction

	USDA Quality Grade		
Muscle	Choice	Select	Standard
Rectus femoris			
Control	$3.48^{c} \pm 0.16$	$3.01^{ab} \pm 0.17$	$4.46^{d} \pm 0.17$
Treated	$2.99^{ab} \pm 0.16$	$3.33^{bc} \pm 0.16$	$2.80^{a} \pm 0.16$
Teres major			
Control	$4.73^{d} \pm 0.14$	$3.78^{b} \pm 0.10$	$4.13^{c} \pm 0.11$
Treated	$3.33^{a} \pm 0.13$	$3.70^{b} \pm 0.10$	$3.40^{a} \pm 0.10$

[a,b,c,d]Means without a common superscript differ ($P < 0.01$)

Table 14. Least squares means[a] and standard errors for Warner-Bratzler shear values (kg) of steaks from the Supraspinatus

	USDA Quality Grade		
Treatment	Choice	Select	Standard
Control	4.76 ± 0.39	4.38 ± 0.39	4.63 ± 0.39
Treated	4.35 ± 0.39	4.47 ± 0.39	5.01 ± 0.41

[a]None of the means were statistically different.

Table 15. Denuded muscle yield (as a % of sub-primal weight) and amount of purge loss for round muscles from various USDA quality grades

Muscle	% Yield				Purge (kg)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Biceps femoris								
Choice	53.88	4.42	45.25	60.49	0.07	0.06	0.02	0.29
Select	61.96	3.34	57.09	66.63	0.13	0.05	0.01	0.21
Standard	42.10	5.32	33.82	54.42	0.15	0.07	0.05	0.29
Semimembranosus								
Choice	49.94	2.82	45.65	54.76	0.21	0.06	0.13	0.40
Select	52.27	2.74	46.42	56.12	0.21	0.08	0.05	0.44
Standard	42.27	3.03	36.54	46.81	0.17	0.09	0.00	0.32
Rectus femoris								
Choice	25.05	2.61	18.77	29.82	0.03	0.02	0.00	0.08
Select	24.59	2.33	18.05	27.90	0.04	0.08	0.00	0.34
Standard	23.54	2.07	19.41	28.16	0.07	0.08	0.00	0.34
Vastus lateralis								
Choice	34.62	1.99	31.27	39.41	0.03	0.02	0.00	0.08
Select	34.39	1.12	32.25	36.30	0.04	0.08	0.00	0.34
Standard	30.64	2.16	25.52	34.92	0.07	0.08	0.00	0.34

Table 16. Denuded muscle yield (as a % of sub-primal weight) and amount of purge loss for chuck muscles from various USDA quality grades

Muscle	% Yield				Purge (kg)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Infraspinatus								
Choice	15.48	2.11	12.51	19.98	0.11	0.05	0.03	0.21
Select	17.83	1.96	14.33	21.43	0.15	0.08	0.03	0.31
Standard	15.31	2.25	10.89	19.82	0.15	0.09	0.00	0.30
Triceps brachii								
Choice	26.02	2.48	21.01	29.64	0.11	0.05	0.03	0.21
Select	27.25	2.01	23.26	30.40	0.15	0.08	0.03	0.31
Standard	27.10	2.42	23.14	33.23	0.15	0.09	0.00	0.30
Teres major								
Choice	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Select	3.04	0.60	1.98	4.00	0.15	0.08	0.03	0.31
Standard	3.27	0.65	2.00	4.97	0.15	0.09	0.00	0.30
Supraspinatus								
Choice	83.47	4.26	74.89	88.85	0.00	0.00	0.00	0.00
Select	83.76	2.23	81.19	86.84	0.19	0.06	0.08	0.27
Standard	71.13	3.78	66.21	77.20	0.20	0.15	0.09	0.54

Table 17. Steak yield and number of 0.2 kg steaks from each denuded muscle

	Steak yield, % of denuded muscle				Number of 0.2 kg steaks obtained			
Muscle	Mean	SD	Min	Max	Mean	SD	Min	Max
Biceps femoris	81.56	3.97	70.73	87.88	15.60	2.49	12.00	21.00
Infraspinatus	60.10	9.03	36.84	76.19	5.17	1.15	3.00	7.00
Rectus femoris	82.20	9.12	50.00	100.00	4.53	1.07	2.00	6.00
Semimembranosus	87.45	4.07	80.00	94.34	20.67	2.70	16.00	27.00
Supraspinatus	82.31	6.76	68.75	93.33	4.87	0.86	4.00	7.00
Teres major	63.61	14.95	44.44	100.00	1.07	0.25	1.00	2.00
Triceps brachii	46.00	4.26	35.13	54.79	6.70	0.92	5.00	9.00
Vastus lateralis	85.47	7.36	64.71	94.12	6.73	1.20	4.00	9.00

Table 18. Fabrication time for sub-primal fabrication into denuded muscles

	Fabrication time (s)			
Sub-primal	Mean	SD	Min	Max
Outside round	94.60	16.01	60.00	117.00
Inside round	238.60	24.75	210.00	286.00
Shoulder clod	238.80	57.35	148.00	349.00
Knuckle	120.22	18.05	96.00	157.00

Table 19. Fabrication times for denuded muscle fabrication into steaks

	Fabrication time (s)			
Muscle	Mean	SD	Min	Max
Biceps femoris	151.30	31.04	102.00	230.00
Infraspinatus	105.13	19.12	64.00	151.00
Rectus femoris	45.53	16.41	16.00	86.00
Semimembranosus	130.30	21.52	94.00	183.00
Supraspinatus	32.30	8.22	3.00	44.00
Teres major	18.47	9.53	0.00	37.00
Triceps brachii	115.63	22.40	71.00	169.00
Vastus lateralis	47.07	11.76	28.00	73.00

CHAPTER V

Chemical analysis of beef chuck and round muscles from various USDA quality grades

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ABSTRACT: Individual beef chuck and round muscles representing various USDA quality grades (Choice, Select, and Standard) were evaluated to determine the chemical properties of these muscles among differing USDA quality grades. Four chuck muscles (infraspinatus, triceps brachii, teres major, and supraspinatus) and four round muscles (rectus femoris, vastus lateralis, biceps femoris, and semimembranosus) were utilized in this study. Individual muscles were trimmed free of visible connective tissue and further processed into 0.2 kg portion sized steaks. Proximate analysis samples were obtained from each muscle and grade to determine moisture, fat and protein content. Generally speaking, moisture and protein levels of the chuck and round muscles were typical, with moisture ranging from 73.04% to 76.96% and protein ranging from 19.59% to 23.75%. There was an inverse relationship between percentage fat and percentage moisture, with fat being the most variable component analyzed. Among all muscles analyzed, there was a significant grade effect for percentage fat. Fat levels ranged from 1.15% to 7.15%. Typically, muscles receiving higher trained sensory panel and consumer panel scores also had higher fat contents.

Key Words: Beef, Chuck, Proximate Analysis, Moisture, Protein, Fat

Introduction

Muscle is composed of four major components: moisture, fat, protein, and mineral (ash). Of these components, moisture is the most abundant followed by protein, fat, and ash respectively. While fat is typically found in relatively small proportions compared to the other components of muscle it is often the most variable component of muscle. The perception of fat, with respect to consumers, is also highly variable. Some consumers see fat, specifically intramuscular fat or marbling, as a sign of high quality, while other consumers see any fat as unhealthy. It will become more important for the beef industry to strategically market different cuts and quality grades of beef to those two distinct markets. However, the challenge will be to maintain a consistent, high quality, and flavorful product. The objective of this research was to determine the chemical composition of eight different beef muscles and how they might vary among various USDA quality grades.

Materials and Methods

Sub-primals. Beef chuck and round sub-primals consisting of the shoulder clod, Institutional Meat Purchase Specifications (IMPS) #114 (NAMP, 1997); chuck tender, IMPS #116B (NAMP, 1997); knuckle, IMPS #167A (NAMP, 1997); inside round, IMPS #169A (NAMP, 1997); and outside round, IMPS #171B (NAMP, 1997) were obtained from a federally inspected beef processing plant in Dodge City, Kansas and shipped to the Food and Agricultural Products Center (FAPC) at Oklahoma State University. Sample sizes within each quality grade consisted of: shoulder clod, n = 35 per grade; chuck tender, n = 35 per grade; knuckle, n = 30 per grade; inside round, n = 20 per grade;

and outside round, n = 20 per grade. Upon arrival, the sub-primals were fabricated into individual muscles and completely denuded of fat and connective tissue using a Townsend® skinner (Townsend Engineering Co., Des Moines, IA). Individual muscles were then vacuum packaged and stored in a 4°C cooler until transport to National Steak and Poultry (NSP) in Owasso, Oklahoma for further processing.

Fabrication. Muscles were randomly segregated into two groups (a treated group and a control group) to obtain an equal representation of each muscle and grade per treatment. The control muscles were fabricated into 0.2 kg steaks by expert cutters at NSP, and samples for proximate analysis were randomly selected from 10 control muscles per USDA quality grade. All samples were individually packaged and frozen at -30°C. After the samples were completely frozen they were stored at -10°C until further analysis.

Proximate Analysis. Proximate analysis procedures were carried out on samples taken from non-treated muscles, within three USDA quality grades (Choice, Select, and Standard) to determine the moisture, fat, and protein content. Moisture, fat, and protein determination were preformed in duplicate on powdered samples from each muscle. Samples were powdered in a refrigerated room by individually submerging frozen samples in liquid nitrogen and then pulverizing those samples in a Waring® Commercial Blender (Model 31BL46, Waring Products Division Dynamic Corporation of America, New Hartford, CT.).

Moisture analysis was determined using an Association of Official Analytical Chemists (AOAC, 1980) approved procedure where samples were dried at 100°C for 24 h in an oven (Model 655F, Fisher Scientific, Pittsburgh, PA). Moisture values were calculated using the equation:

$$\%Moisture = (wet\ wt. - dry\ wt.)/ (wet\ wt. - thimble\ wt.) \times 100$$

Fat analysis was determined using modified Goldfish Soxhlet ether extraction (AOAC, 1980). Lipid values were determined using the equation:

$$\%\ Fat = (dry\ wt. - extracted\ wt.)/ (wet\ wt. - thimble\ wt.) \times 100$$

Finally, protein was determined by a direct combustion nitrogen determinator (Model FP-428, LECO Corporation, St. Joseph, MI).

Statistics. Proximate analysis data were analyzed using least squares analysis of variance (PROC GLM; SAS Institute, Cary, NC). Model included muscle and quality grade to evaluate their effect on the percentage moisture, protein and fat. Means were separated using least significant difference.

Results and Discussion

Tables 20 and 21 show the relative differences of moisture, fat, and protein, among the different muscles, according to USDA quality grade. Mean moisture and protein levels fell within the "normal" ranges, with moisture ranging from 73.04% to 76.96% and protein ranging from 19.59% to 23.75%.

Fat was the most variable component analyzed, with mean fat levels ranging from 1.15% to 7.15%. There was an inverse relationship between percentage fat and percentage moisture. These findings are in agreement with the data presented by Cecchi et al. (1988), which suggested that moisture and fat levels are highly inversely related. Mean moisture and fat levels in this study differ from those reported by Von Seggern (2000) and the USDA national nutrient database (USDA, 2002). Lower fat levels and higher moisture levels were found in this study when compared to the other two reports. However, the numbers reported by the USDA which most closely resemble the muscles and fat levels used in our study, are based on cooked samples which would undoubtedly effect nutrient levels.

There was a significant grade effect for percentage fat among all muscles analyzed with USDA Choice muscles typically having higher percentage fat levels. This excludes the teres major and triceps brachii muscles which both had mean fat levels higher for USDA Select muscles. Typically, muscles with higher fat contents received more favorable trained sensory panel and consumer panel scores during the corresponding phases of this project. This is in direct agreement with the data presented by McKeith et al. (1985) which showed of the muscles evaluated in their study, the four muscles with the highest fat contents were rated as the most tender and flavorful by sensory panelists, suggesting a relationship between fat content and palatability.

The chemical composition of beef chuck muscles are presented in Table 20. The chemical composition of beef round muscles are presented in Table 21. Excluding the infraspinatus, which had the highest mean percentage fat of all muscles sampled, the mean fat contents of the remaining muscles are not dissimilar. This contradicts the findings of Brackebusch et al. (1991) and McKeith et al. (1985) which both suggested that the muscles of the round had lower fat contents than the muscles of the chuck.

Implications

With consumers becoming more health conscious everyday, identifying the chemical composition of various beef muscles will become more and more important. The known chemical composition of various beef chuck and round muscles along with Warner-Bratzler shear force and sensory data will help the beef industry better utilize and market these cuts to consumers.

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Table 20. Least squares means and standard errors for moisture, fat, and protein content of muscles isolated from the beef chuck

	USDA Quality Grade		
Muscle	Choice	Select	Standard
Infraspinatus			
%Moisture	$72.64^{a} \pm 0.44$	$73.04^{a} \pm 0.44$	$75.02^{b} \pm 0.44$
%Fat	$7.15^{a} \pm 0.52$	$5.75^{a} \pm 0.52$	$4.17^{b} \pm 0.52$
%Protein	$19.59^{a} \pm 0.19$	$20.51^{b} \pm 0.19$	$20.73^{b} \pm 0.19$
Supraspinatus			
%Moisture	$74.83^{a} \pm 0.24$	$75.22^{a} \pm 0.28$	$76.81^{b} \pm 0.28$
%Fat	$3.16^{a} \pm 0.18$	$3.15^{a} \pm 0.21$	$1.37^{b} \pm 0.21$
%Protein	21.42 ± 0.24	21.92 ± 0.27	21.38 ± 0.27
Teres major			
%Moisture	$74.51^{a} \pm 0.35$	$73.88^{a} \pm 0.27$	$75.97^{b} \pm 0.27$
%Fat	$3.82^{a} \pm 0.35$	$4.13^{a} \pm 0.27$	$1.84^{b} \pm 0.27$
%Protein	$23.22^{a} \pm 0.21$	$23.55^{a} \pm 0.16$	$22.00^{b} \pm 0.16$
Triceps brachii			
% Moisture	$76.30^{ab} \pm 0.33$	$75.67^{a} \pm 0.25$	$76.96^{b} \pm 0.26$
%Fat	$1.41^{a} \pm 0.19$	$2.30^{b} \pm 0.14$	$1.15^{a} \pm 0.14$
%Protein	21.32 ± 0.34	21.96 ± 0.25	21.78 ± 0.26

[a,b]Within a row means without a common superscript letter differ ($P < 0.01$)

Table 21. Least squares means and standard errors for moisture, fat, and protein content of muscles isolated from the beef round

	USDA Quality Grade		
Muscle	Choice	Select	Standard
Biceps femoris			
%Moisture	$73.14^{a} \pm 0.22$	$73.63^{a} \pm 0.23$	$74.30^{b} \pm 0.23$
%Fat	$3.40^{a} \pm 0.26$	$2.61^{b} \pm 0.27$	$2.45^{b} \pm 0.27$
%Protein	$22.72^{a} \pm 0.24$	$21.98^{b} \pm 0.25$	$22.98^{a} \pm 0.25$
Rectus femoris			
%Moisture	$74.69^{a} \pm 0.25$	$75.30^{a} \pm 0.31$	$76.51^{b} \pm 0.25$
%Fat	$3.43^{a} \pm 0.20$	$2.36^{b} \pm 0.25$	$1.10^{c} \pm 0.20$
%Protein	21.74 ± 0.24	21.67 ± 0.30	22.32 ± 0.24
Semimembranosus			
%Moisture	74.05 ± 0.25	74.19 ± 0.24	74.58 ± 0.26
%Fat	$2.51^{a} \pm 0.23$	$1.40^{b} \pm 0.22$	$1.41^{b} \pm 0.25$
%Protein	$22.68^{a} \pm 0.22$	$23.18^{ab} \pm 0.21$	$23.75^{b} \pm 0.23$
Vastus lateralis			
%Moisture	$74.12^{a} \pm 0.25$	$75.64^{b} \pm 0.18$	$76.12^{b} \pm 0.24$
%Fat	$3.25^{a} \pm 0.20$	$2.23^{b} \pm 0.14$	$1.32^{c} \pm 0.19$
%Protein	21.85 ± 0.30	22.56 ± 0.29	21.88 ± 0.22

[a,b,c]Within a row means without a common superscript letter differ ($P < 0.05$)

APPENDIX

Appendix A

CONSUMER SENSORY QUESTIONNAIRE

Please Fill Out The Following Information. Panelist Number: _______________

1. Please indicate your age by marking the appropriate blank:

_____ Under 20 years _____ 30-39 years _____ 50-59 years

_____ 20-29 years _____ 40-49 years _____ 60 years or older

2. Please indicate your household size, including yourself:

_____ 1 _____ 3 _____ 5

_____ 2 _____ 4 _____ 6 or more

3. Please indicate your current working status by marking the appropriate blank:

_____ Student _____ Not employed _____ Part-time _____ Full-time

4. Please indicate your gender:

_____ Female _____ Male

5. Please indicate how often you consume steak in/from a foodservice establishment:

_____ < 1 time / month _____ 1-2 times / month _____ 2-4 times / month

_____ 1-2 times / week _____ 2-4 times / week _____ > 5 times / week

6. Please indicate your highest level of education:

_____Elementary school _____Junior high/middle school _____ High school

_____College/university _____ Graduate school, professional degree, etc.

7. From which one type of foodservice establishment do you purchase food most often?

_____Fast food chain (McDonald's, Taco Bell, Subway, etc)

_____Family restaurant chain (Denny's, Perkins, IHOP)

_____Casual restaurant chain (Pizza Hut, Chili's, Applebee's)

Appendix A

_____Cafeteria (Furr's, Luby's, etc.)

_____Ethnic (Chinese, Thai, Mexican, Italian)

_____Fine Dining (Ruth's Chris, 501 Ranch, Freddie's Steakhouse)

_____Bakery (St. Louis Bread Co., Manhattan Bagel Co.)

8. What USDA quality grade are the steaks that you most often eat from a foodservice establishment?

_____ Don't know _____ Prime _____ Choice

_____ Certified Angus Beef _______________ Other (please list)

9. Do you go out of your way to eat steak in or from an establishment that offers a specific quality grade?

_____ No _____Yes

10. What degree of doneness do you usually request your steak to be prepared to in foodservice establishments?

_____Very Rare (inside is almost raw and cool)

_____Rare (inside is red and cool)

_____Medium rare (inside is pink-to-red and warm)

_____Medium (some pink inside)

_____Medium well (very little pink inside)

_____Well done (cooked throughout; no pink inside)

_____Very well done (almost charred on the outside; no pink inside)

11. How do you prefer to eat your steak from a foodservice establishment?

_____Plain

_____Seasoned (such as salt and pepper on the surface)

_____Marinated (flavor throughout the steak)

_____With butter

_____With a sauce (A-1, ketchup, bordelaise, etc.)

Appendix A

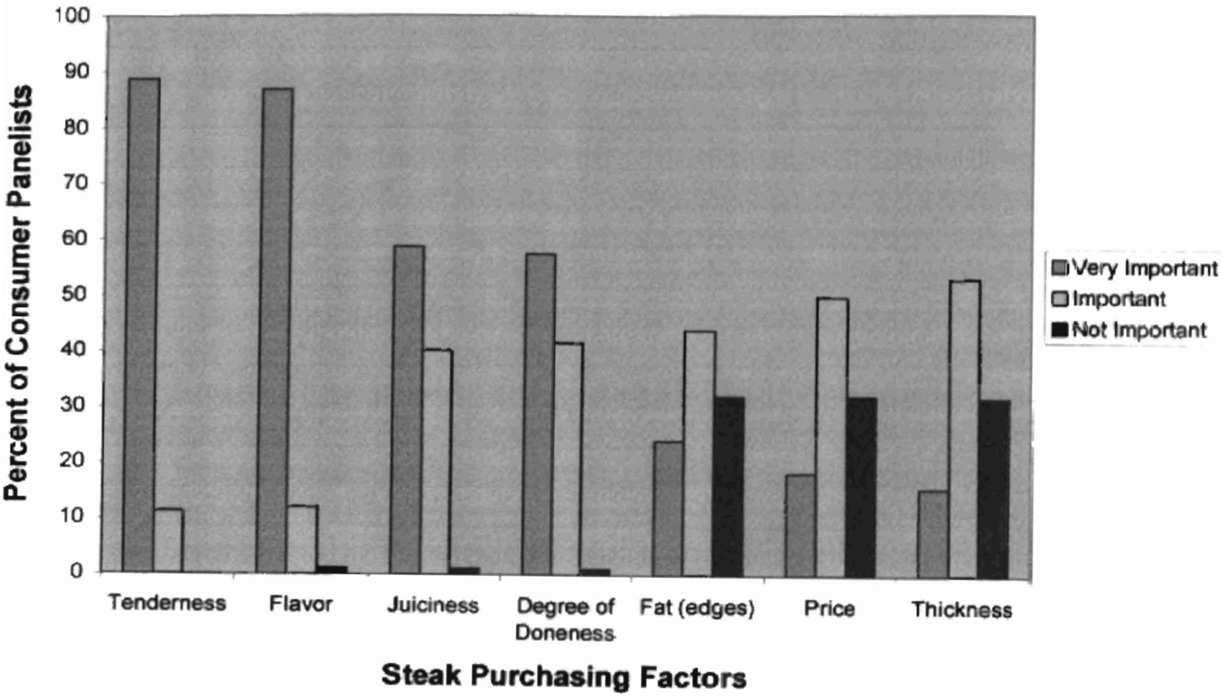
12. Listed below are some factors you might consider when deciding if you would eat the same steak again in or from a foodservice establishment. Please assign a number to <u>each</u> factor that corresponds to how important the factor is in your decision to eat the same steak again.

1 = very important **2 = important** **3 = not important**

_____Tenderness	_____Steak thickness	_____Amount of fat on the edge(s)
_____Amount of flavor	_____Juiciness	_____Cooked to correct doneness
_____Price	_______________ Other (please list)	

Appendix B

Figure 1. **Factors Affecting Steak Purchase**



Appendix C

CONSUMER SENSORY EVALUATION

SAMPLE #1

PANELIST NUMBER: ____________ SAMPLE NUMBER: ____________

1. Indicate, by placing a mark in the box, your OVERALL LIKE/DISLIKE of this sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely				Neither like nor dislike				Like extremely

2. Indicate, by placing a mark in the box, your LIKE/DISLIKE of the FLAVOR of this sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely				Neither like nor dislike				Like extremely

3. Indicate, by placing a mark in the box, the JUICINESS of this sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Very dry				Slightly dry/ slightly juicy				Very juicy

4. Indicate, by placing a mark in the box, the TENDERNESS of this sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Very tough				Slightly tough/ slightly tender				Very tender

5. If this steak were offered to you on a foodservice menu, would you purchase it?

☐	☐	☐	☐	☐
Definitely Would not buy	Probably not buy	Might/might not buy	Probably buy	Definitely would buy

6. Comments:

____

____

Appendix D

NCBA / ELAM PROJECT
SENSORY BALLOT

BOOTH # _________ DATE: ___________ TIME: _________AM/PM

Sample	Tenderness	Juiciness	Connective Tissue Amount	Uncharacteristic Flavor	Overall Acceptability	Comments
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

<u>Tenderness</u>
8 Extremely tender
7 Very tender
6 Moderately tender
5 Slightly tender
4 Slightly tough
3 Moderately tough
2 Very tough
1 Extremely tough

<u>Juiciness</u>
8 Extremely juicy
7 Very juicy
6 Moderately juicy
5 Slightly juicy
4 Slightly dry
3 Moderately dry
2 Very dry
1 Extremely dry

<u>Overall Acceptability</u>
8 Extremely desirable
7 Moderately desirable
6 Desirable
5 Slightly desirable
4 Slightly undesirable
3 Undesirable
2 Moderately undesirable
1 Extremely undesirable

<u>Connective Tissue Amount</u>
8 None
7 Practically none
6 Traces
5 Slight
4 Moderate
3 Slightly Abundant
2 Moderately Abundant
1 Abundant

<u>Uncharacteristic Flavor</u>
4 None
3 Slight
2 Moderate
1 Extremely uncharacteristic

Appendix E

Table 22. Least squares means of consumer responses for non-treated muscles including Certified Angus Beef

	Sensory Characteristic				
Muscle	Overall[f]	Flavor[g]	Juiciness[h]	Tenderness[i]	Purchase[j]
Triceps bracii	4.5^{ab}	4.5^{ab}	4.5^{ab}	4.7^{abc}	2.5^{abc}
Infraspinatus	6.3^{de}	5.9^{cd}	6.4^{c}	6.5^{de}	3.4^{de}
Teres major	5.9^{cde}	5.5^{bcd}	5.5^{bc}	6.0^{cde}	3.1^{bcde}
Biceps femoris	4.9^{abc}	5.4^{bc}	5.3^{b}	4.9^{abc}	2.6^{abc}
Semimembranosus	4.7^{ab}	4.7^{ab}	4.8^{ab}	3.9^{a}	2.4^{ab}
Vastus lateralis	4.0^{a}	4.2^{a}	4.1^{a}	3.9^{ab}	2.1^{a}
Rectus femoris	6.1^{de}	5.8^{cd}	5.0^{ab}	5.4^{cd}	3.2^{cde}
Supraspinatus	5.4^{bcd}	5.5^{bc}	5.7^{bc}	4.9^{bc}	2.8^{bcd}
Certified Angus Beef	6.4^{e}	6.4^{d}	6.4^{c}	6.5^{e}	3.5^{e}

[a,b,c,d,e]Within a column means without a common superscript letter differ ($P < 0.05$)

[f]Overall: 4 = slightly dislike; 5 = neither like nor dislike; 6 = slightly like

[g]Flavor: 4 = slightly dislike; 5 = neither like nor dislike; 6 = slightly like

[h]Juiciness: 4 = moderately dry; 5 = slightly dry / slightly juicy; 6 = moderately juicy

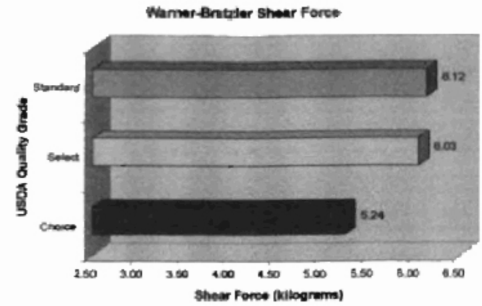
[i]Tenderness: 3 = tough; 4 = moderately tough; 5 = slightly tough / slightly tender; 6 = moderately tender

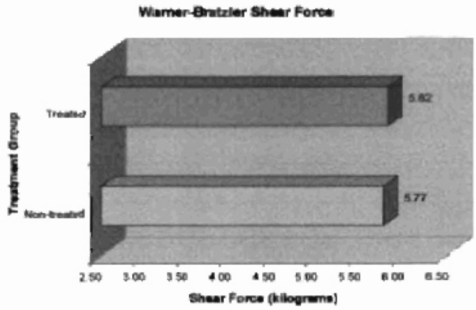
[j]Purchase: 2 = Probably would not buy if this steak were offered on foodservice menu; 3 = Might or might not buy if this steak were offered on a foodservice menu

Appendix F

Muscle Profile Summary

Biceps femoris





Consumer Evaluation

Item	Response
Overall	Neither like nor dislike
Flavor	Slightly like
Juiciness	Slightly dry / slightly juicy
Tenderness	Slightly tough / slightly tender
Purchase Intent	Might or might not buy

Trained Sensory Evaluation by Grade

Item	USDA Choice	USDA Select	USDA Standard
Tenderness	Slightly tender	Slightly tender	Slightly tender
Juiciness	Slightly juicy	Slightly juicy	Slightly dry
Uncharacteristic Flavor	Slight	Slight	Slight
Connective Tissue Amount	Slight	Moderate	Moderate
Overall Acceptability	Slightly undesirable	Slightly undesirable	Slightly undesirable

Trained Sensory Evaluation by Treatments

Item	Non-treated	Treated
Tenderness	Slightly tough	Slightly tender
Juiciness	Slightly dry	Slightly juicy
Uncharacteristic Flavor	Slight	Slight
Connective Tissue Amount	Moderate	Slight
Overall Acceptability	Slightly undesirable	Slightly undesirable

Proximate Analysis

Item	Choice	Select	Standard
% Moisture	73.14	73.63	74.30
% Fat	3.40	2.61	2.45
% Protein	22.72	21.98	22.98

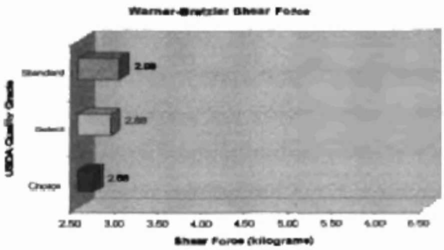
Yield Data

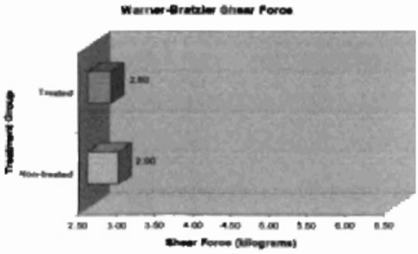
	% Yield of Sub-primal				Purge (lb)			
Quality Grade	Mean	SD	Min	Max	Mean	SD	Min	Max
Choice	53.88	4.42	45.25	60.49	0.16	0.14	0.04	0.64
Select	61.96	3.34	57.09	66.63	0.29	0.12	0.02	0.46
Standard	42.10	5.32	33.82	54.42	0.33	0.16	0.12	0.64

Steak Yield Data

Item	Mean	SD	Min	Max
# of 7 oz steaks	15.60	2.49	12.00	21.00
% yield of steaks	81.56	3.97	70.73	87.88
Fabrication time, s	151.30	31.04	102.00	230.00

Infraspinatus





Consumer Evaluation

Item	Response
Overall	Like
Flavor	Slightly like
Juiciness	Very juicy
Tenderness	Very tender
Purchase Intent	Might or might not buy

Trained Sensory Evaluation by Grade

	Response		
Item	**USDA Choice**	**USDA Select**	**USDA Standard**
Tenderness	Moderately tender	Moderately tender	Moderately tender
Juiciness	Slightly juicy	Slightly juicy	Moderately juicy
Uncharacteristic Flavor	Slight	Slight	Slight
Connective Tissue Amount	Slight	Traces	Traces
Overall Acceptability	Slightly desirable	Desirable	Desirable

Trained Sensory Evaluation by Treatments

	Response	
Item	**Non-treated**	**Treated**
Tenderness	Moderately tender	Moderately tender
Juiciness	Moderately juicy	Moderately juicy
Uncharacteristic Flavor	Slight	Slight
Connective Tissue Amount	Slight	Traces
Overall Acceptability	Slightly Desirable	Slightly Desirable

Proximate Analysis

	USDA Quality Grade		
Item	**Choice**	**Select**	**Standard**
% Moisture	72.64	73.04	75.02
% Fat	7.15	5.75	4.17
% Protein	19.59	20.51	20.73

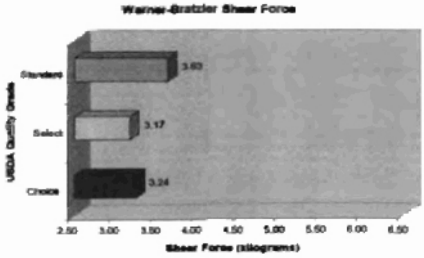
Yield Data

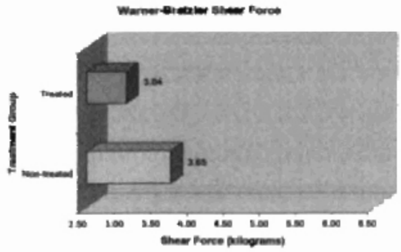
	% Yield of Sub-primal				Purge (lb)			
Quality Grade	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Choice	15.48	2.11	12.51	19.98	0.24	0.11	0.06	0.46
Select	17.83	1.96	14.33	21.43	0.32	0.17	0.06	0.68
Standard	15.31	2.25	10.89	19.82	0.32	0.20	0.00	0.66

Steak Yield Data

Item	Mean	SD	Min	Max
# of 7 oz. Steaks	5.17	1.15	3.00	7.00
% Yield of Steaks	60.10	9.03	36.84	76.19
Fabrication time, s	105.13	19.12	64.00	151.00

Rectus femoris





Consumer Evaluation

Item	Response
Overall	Slightly like
Flavor	Slightly like
Juiciness	Slightly dry / slightly juicy
Tenderness	Moderately tender
Purchase Intent	Might or might not buy

Trained Sensory Evaluation by Grade

	Response		
Item	USDA Choice	USDA Select	USDA Standard
Tenderness	Moderately tender	Slightly tender	Slightly tender
Juiciness	Slightly juicy	Slightly juicy	Slightly dry
Uncharacteristic Flavor	Slight	Slight	Slight
Connective Tissue Amount	Slight	Slight	Slight
Overall Acceptability	Slightly desirable	Slightly desirable	Slightly undesirable

Trained Sensory Evaluation by Treatments

	Response	
Item	Non-treated	Treated
Tenderness	Slightly tender	Slightly tender
Juiciness	Slightly juicy	Slightly juicy
Uncharacteristic Flavor	Slight	Slight
Connective Tissue Amount	Slight	Slight
Overall Acceptability	Slightly desirable	Slightly desirable

Proximate Analysis

	USDA Quality Grade		
Item	Choice	Select	Standard
% Moisture	74.69	75.30	76.51
% Fat	3.43	2.36	1.10
% Protein	21.74	21.67	22.32

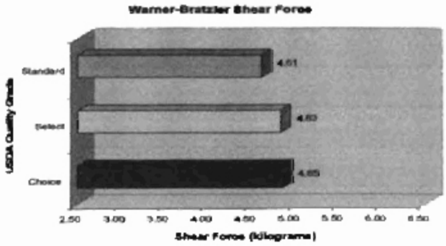
Yield Data

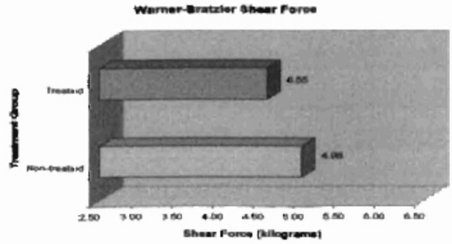
	% Yield of Sub-primal				Purge (lb)			
Quality Grade	Mean	SD	Min	Max	Mean	SD	Min	Max
Choice	25.05	2.61	18.77	29.82	0.07	0.05	0.00	0.18
Select	24.59	2.33	18.05	27.90	0.09	0.17	-0.02	0.76
Standard	23.54	2.07	19.41	28.16	0.15	0.17	-0.04	0.76

Steak Yield Data

Item	Mean	SD	Min	Max
# of 7 oz. Steaks	4.53	1.07	2.00	6.00
% Yield of Steaks	82.20	9.12	50.00	100.00
Fabrication time, s	45.53	16.41	16.00	86.00

Semimembranosus





Consumer Evaluation

Item	Response
Overall	Neither like nor dislike
Flavor	Neither like nor dislike
Juiciness	Slightly dry / slightly juicy
Tenderness	Slightly tough / slightly tender
Purchase Intent	Might or might not buy

Trained Sensory Evaluation by Grade

	Response		
Item	USDA Choice	USDA Select	USDA Standard
Tenderness	Slightly tender	Slightly tender	Slightly tender
Juiciness	Slightly juicy	Slightly dry	Slightly juicy
Uncharacteristic Flavor	Slight	Slight	Slight
Connective Tissue Amount	Slight	Slight	Slight
Overall Acceptability	Slightly undesirable	Slightly undesirable	Slightly undesirable

Trained Sensory Evaluations by Treatments

	Response	
Item	Non-treated	Treated
Tenderness	Slightly tough	Slightly tender
Juiciness	Slightly dry	Slightly juicy
Uncharacteristic Flavor	Slight	Slight
Connective Tissue Amount	Slight	Slight
Overall Acceptability	Slightly undesirable	Slightly desirable

Proximate Analysis

	USDA Quality Grade		
Item	Choice	Select	Standard
% Moisture	74.05	74.19	74.58
% Fat	2.51	1.40	1.14
% Protein	22.68	23.18	23.75

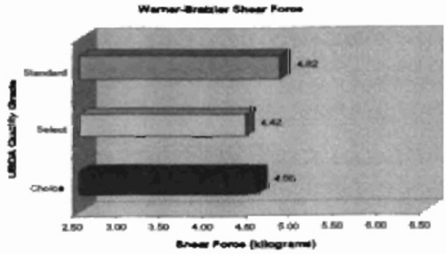
Yield Data

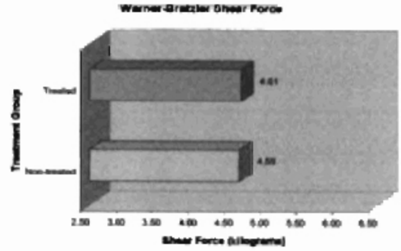
	% Yield of Sub-primal				Purge (lb)			
Quality Grade	Mean	SD	Min	Max	Mean	SD	Min	Max
Choice	49.94	2.82	45.65	54.76	0.47	0.14	0.28	0.88
Select	52.27	2.74	46.42	56.12	0.46	0.18	0.10	0.96
Standard	42.27	3.03	36.54	46.81	0.37	0.20	0.00	0.7

Steak Yield Data

Item	Mean	SD	Min	Max
# of 7 oz. Steaks	20.67	2.70	16.00	27.00
% Yield of Steaks	87.45	4.07	80.00	94.34
Fabrication time, s	130.30	21.52	94.00	183.00

Supraspinatus





Consumer Evaluation

Item	Response
Overall	Slightly like
Flavor	Neither like nor dislike
Juiciness	Slightly dry / slightly juicy
Tenderness	Slightly tough / slightly tender
Purchase Intent	Might or might not buy

Trained Sensory Evaluation by Grade

	Response		
Item	USDA Choice	USDA Select	USDA Standard
Tenderness	Slightly tender	Slightly tender	Slightly tender
Juiciness	Slightly juicy	Slightly dry	Slightly juicy
Uncharacteristic Flavor	Slight	Slight	Slight
Connective Tissue Amount	Slight	Slight	Moderate
Overall Acceptability	Slightly undesirable	Slightly undesirable	Slightly undesirable

Trained Sensory Evaluations by Treatment

	Response	
Item	Non-treated	Treated
Tenderness	Slightly tender	Slightly tender
Juiciness	Slightly dry	Slightly juicy
Uncharacteristic Flavor	Slight	Slight
Connective Tissue Amount	Moderate	Slight
Overall Acceptability	Slightly undesirable	Slightly undesirable

Proximate Analysis

	USDA Quality Grade		
Item	Choice	Select	Standard
% Moisture	74.83	75.22	76.81
% Fat	3.16	3.15	1.37
% Protein	21.42	21.92	21.38

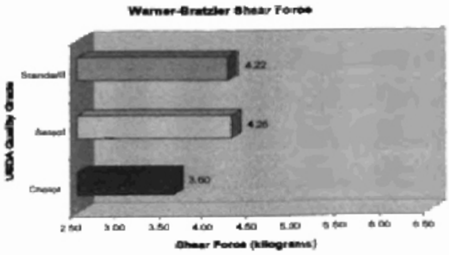
Yield Data (n = 5)

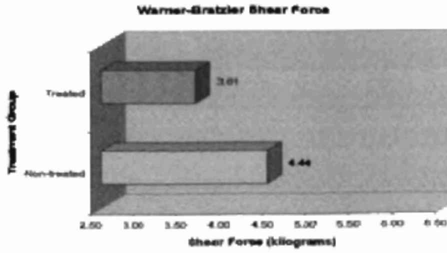
	% Yield				Purge (lb)			
Quality Grade	Mean	SD	Min	Max	Mean	SD	Min	Max
Choice	83.47	4.26	74.89	88.85	0.00	0.00	0.00	0.00
Select	83.76	2.23	81.19	86.84	0.41	0.13	0.18	0.60
Standard	71.13	3.78	66.21	77.29	0.45	0.33	0.20	1.18

Steak Yield Data

Item	Mean	SD	Min	Max
# of 7 oz. Steaks	4.87	0.86	4.00	7.00
% Yield of Steaks	82.31	6.76	68.75	93.33
Fabrication time, s	32.30	8.22	3.00	44.00

Triceps brachii





Consumer Evaluation

Item	Response
Overall	Neither like nor dislike
Flavor	Neither like nor dislike
Juiciness	Slightly dry / slightly juicy
Tenderness	Slightly tough / slightly tender
Purchase Intent	Might or might not buy

Trained Sensory Evaluation by Grade

	Response		
Item	USDA Choice	USDA Select	USDA Standard
Tenderness	Slightly tender	Slightly tough	Slightly tender
Juiciness	Slightly juicy	Slightly juicy	Slightly juicy
Uncharacteristic Flavor	Slight	Slight	Slight
Connective Tissue Amount	Slight	Moderate	Slight
Overall Acceptability	Slightly desirable	Slightly undesirable	Slightly desirable

Trained Sensory Evaluations by Treatment

	Response	
Item	Non-treated	Treated
Tenderness	Slightly tough	Moderately tender
Juiciness	Slightly dry	Slightly juicy
Uncharacteristic Flavor	Slight	Slight
Connective Tissue Amount	Moderate	Slight
Overall Acceptability	Slightly undesirable	Slightly desirable

Proximate Analysis

	USDA Quality Grade		
Item	Choice	Select	Standard
% Moisture	76.30	75.67	76.96
% Fat	1.41	2.30	1.15
% Protein	21.32	21.96	21.78

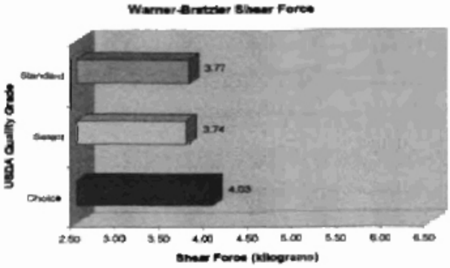
Yield Data

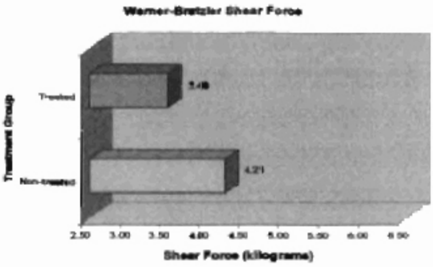
	% Yield of Sub-primal				Purge (lb)			
Quality Grade	Mean	SD	Min	Max	Mean	SD	Min	Max
Choice	26.02	2.48	21.01	29.64	0.24	0.11	0.06	0.46
Select	27.25	2.01	23.26	30.40	0.32	0.17	0.06	0.68
Standard	27.10	2.42	23.14	33.23	0.32	0.20	0.00	0.66

Steak Yield Data

Item	Mean	SD	Min	Max
# of 7 oz. Steaks	6.7	0.92	5.00	9.00
% Yield of Steaks	46.00	4.26	35.13	54.79
Fabrication time, s	115.63	22.40	71.00	169.00

Teres major





Consumer Evaluation

Item	Response
Overall	Slightly like
Flavor	Slightly like
Juiciness	Slightly dry / slightly juicy
Tenderness	Moderately tender
Purchase Intent	Might or might not buy

Trained Sensory Evaluation by Grade

	Response		
Item	USDA Choice	USDA Select	USDA Standard
Tenderness	Moderately tender	Moderately tender	Moderately tender
Juiciness	Moderately juicy	Slightly juicy	Slightly juicy
Uncharacteristic Flavor	Slight	Slight	Slight
Connective Tissue Amount	Slight	Slight	Slight
Overall Acceptability	Slightly desirable	Slightly desirable	Slightly desirable

Trained Sensory Evaluation by Treatments

	Response	
Item	Non-treated	Treated
Tenderness	Moderately tender	Moderately tender
Juiciness	Slightly juicy	Slightly juicy
Uncharacteristic Flavor	Slight	Slight
Connective Tissue Amount	Slight	Slight
Overall Acceptability	Slightly desirable	Slightly desirable

Proximate Analysis

	USDA Quality Grade		
Item	Choice	Select	Standard
% Moisture	74.51	73.88	75.97
% Fat	3.82	4.13	1.84
% Protein	23.22	23.55	22.00

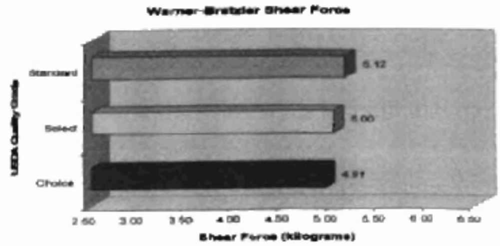
Yield Data

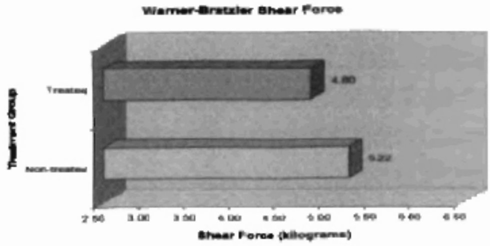
	% Yield of Sub-primal				Purge (lb)			
Quality Grade	Mean	SD	Min	Max	Mean	SD	Min	Max
Select	3.04	0.60	1.98	4.00	0.32	0.17	0.06	0.68
Standard	3.27	0.65	2.00	4.97	0.32	0.20	0.00	0.66

Steak Yield Data

Item	Mean	SD	Min	Max
# of 7 oz. Steaks	1.07	0.25	1.00	2.00
% Yield of Steaks	63.61	14.95	44.44	100.00
Fabrication time, s	18.47	9.53	0.00	37.00

Vastus lateralis





Consumer Evaluation

Item	Response
Overall	Slightly dislike
Flavor	Neither like nor dislike
Juiciness	Moderately dry
Tenderness	Moderately tough
Purchase Intent	Probably would not buy

Trained Sensory Evaluation by Grade

	Response		
Item	USDA Choice	USDA Select	USDA Standard
Tenderness	Slightly tender	Slightly tender	Slightly tender
Juiciness	Slightly juicy	Slightly juicy	Slightly juicy
Uncharacteristic Flavor	Slight	Slight	Slight
Connective Tissue Amount	Slight	Moderate	Slight
Overall Acceptability	Slightly undesirable	Slightly undesirable	Slightly desirable

Trained Sensory Evaluation by Treatments

	Response	
Item	Non-treated	Treated
Tenderness	Slightly tough	Slightly tender
Juiciness	Slightly juicy	Slightly juicy
Uncharacteristic Flavor	Moderate	Slight
Connective Tissue Amount	Slight	Slight
Overall Acceptability	Slightly undesirable	Slightly desirable

Proximate Analysis

	USDA Quality Grade		
Item	Choice	Select	Standard
% Moisture	74.12	75.64	76.12
% Fat	3.25	2.23	1.32
% Protein	21.85	22.56	21.88

Yield Data

	% Yield of Sub-primal				Purge (lb)			
Quality Grade	Mean	SD	Min	Max	Mean	SD	Min	Max
Choice	34.62	1.99	31.27	39.41	0.07	0.05	0.00	0.18
Select	34.39	1.12	32.25	36.30	0.09	0.17	-0.02	0.76
Standard	30.64	2.16	25.52	34.92	0.15	0.17	-0.04	0.76

Steak Yield Data

Item	Mean	SD	Min	Max
# of 7 oz. Steaks	6.73	1.20	4.00	9.00
% Yield of Steaks	85.47	7.36	64.71	94.12
Fabrication time, s	47.07	11.76	28.00	73.00

Oklahoma State University
Institutional Review Board

Protocol Expires: 4/30/02

Date Tuesday, May 01, 2001 IRB Application No AG0133

Proposal Title AN ECONOMIC ASSESSMENT OF VALUE ADDED MEAT PRODUCTS UTILIZING BEEF CHUCK FROM VARIOUS USDA QUALITY GRADES

Principal
Investigator(s).

J Chance Brooks
104 Animal Science
Stillwater OK 74078

Brad Morgan
104 Animal Science
Stillwater, OK 74078

Reviewed and
Processed as Exempt

Approval Status Recommended by Reviewer(s) Approved

Dear PI :

Your IRB application referenced above has been approved for one calendar year. Please make note of the expiration date indicated above. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete

Please note that approved projects are subject to monitoring by the IRB. If you have questions about the IRB procedures or need any assistance from the Board, please contact Sharon Bacher, the Executive Secretary to the IRB, in 203 Whitehurst (phone 405-744-5700, sbacher@okstate.edu)

Sincerely,

Carol Olson

Carol Olson, Chair
Institutional Review Board

2.

VITA

Aaron Thomas Elam

Candidate for the Degree of

Master of Science

Thesis: A MUSCLE PROFILE OF VALUE ADDED BEEF FROM THE CHUCK AND ROUND

Major Field: Animal Science

Biographical:

Personal Data: Born in Pauls Valley, Oklahoma, on January 27, 1978, the son of Joe and Cynthia Elam.

Education: Graduated from Pauls Valley High School, Pauls Valley, Oklahoma in May 1996; received a Bachelor of Science degree in Animal Science from Oklahoma State University, Stillwater, Oklahoma in May 2001. Completed the requirements for the Master of Science degree with a major in Animal Science at Oklahoma State University in August 2003.

Experience: Employed by Oklahoma State University, Animal Science Department as a graduate research and teaching assistant, 2001 to present; employed by Oklahoma State University, Department of Animal Science as a undergraduate research assistant, summer 2000; employed by Oklahoma State University, Food and Agricultural Products Center as a meat lab student worker, summer 1999.

Professional Memberships: American Meat Science Association.